SNOW AND ICE DATABOOK 2018

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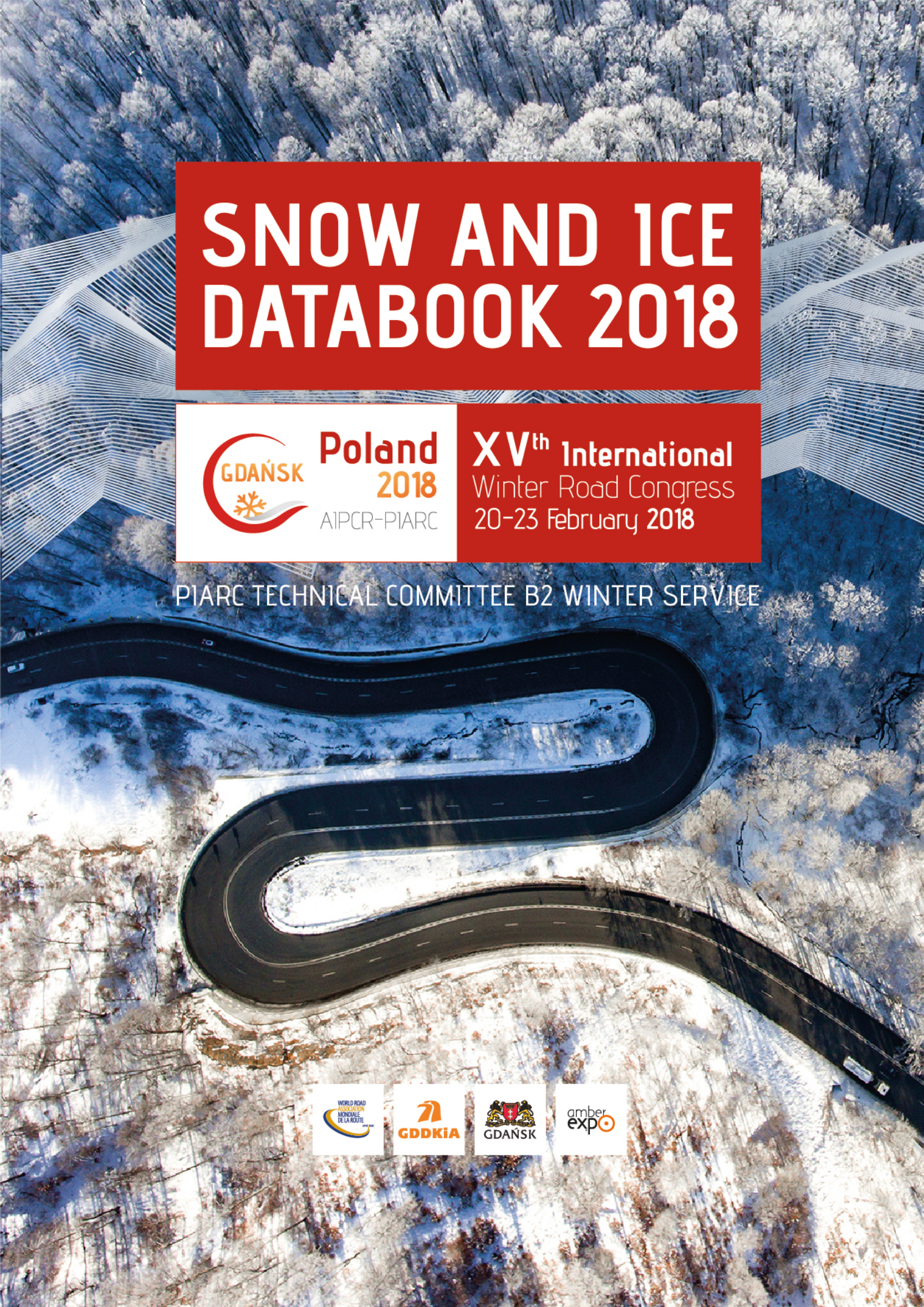
PIARC TECHNICAL COMMITTEE B2 WINTER SERVICE



INTRODUCTION

Though climate change is corresponding to a global warming, at present, it means also more extreme events. In winter it means that we can have a very mild winter one year and a cold and snowy winter the year after. So winter maintenance is very difficult to manage while mobility still increases and budgets decrease. We have to do the best with less money.

The road networks managers must keep infrastructures passable so that the economic activity is not disturbed while guaranteeing the road users safety.

There are different types of road users and different means of locomotion and transport that are affected by road viability: pedestrians, cyclists, public transports, cars, freight carriers; so it is important to propose a global answer in terms of winter maintenance.

It becomes a real challenge, especially in a urban environment and significant resources (human and equipment) are generally provided.

Sustainable development and environment protection are essential subjects so it is necessary to always think about how to define good strategies, how to improve our practices. To move forward in that way, we have to share our experiences.

The ambitious goal of the „snow and ice data book" (SIDB) is to report the experience in winter maintenance of about thirty countries. It has been existing for over fifteen years and its publication every 4 years during the international winter maintenance congress is always a success.

In the SIDB, we have the same structure with the same various chapters written by each country. So this document succeeds to gather the outline of the winter maintenance practices of about thirty countries.

XVth International Winter Road Congress is the opportunity to publish this fifth version of the SIDB.

This edition of the SIDB had been coordinated by a working group within the winter maintenance committee B2, composed of Anna Arvidsson, Tuovi Päiviö, Odile Coudert, Alan Chambers and Didier Giloppé without forgetting all the other committee members who enable the SIDB updating as well as many external participants.

We also have to thank the Polish organising Committee, and especially Aleksandra Cybulska who very actively contributed to the publication of the SIDB and to the organization of the XVth International Winter Road Congress.

We hope that this manual will constitute a useful and user-friendly reference work for all the actors of winter service: contracting authority, project manager, stakeholders and road users.

For the whole committee
Didier Giloppé
Chairman of PIARC Technical Committee
B2 winter service

INDEX

ANDORRA

1. DEMOGRAPHIC AND ROADS

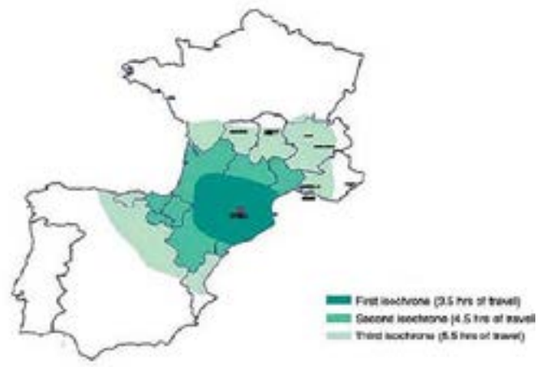
1.1. INFORMATION ABOUT THE COUNTRY

The Principality of Andorra is a microstate (468 km2) located between Spain and France, in the middle of the Pyrenees mountain range. The current population is over 85,000 inhabitants, with a density of 182 inhabitants/km2, with the majority of the population concentrated on the valley floors. The key economic sectors are construction and its derivatives, the financial sector, and above all the restaurant industry and trade. Every year more than 11 million tourists visit the country (approximately 80% leave the same day and 20% stay at least one night in the country), attracted mostly by the retail offerings and mountain sports, particularly in winter (the Principality of Andorra has the highest concentration of ski resorts in the Pyrenees, 315 km of trails)

OFFICIAL ROAD MAP

Administratively, the country is divided into seven parishes: Canillo, Encamp, Ordino, La Massana, Andorra la Vella, Sant Julià de Lòria and Escaldes -Engordany. More than half of the country's population is concentrated in the two major agglomerations of Andorre la Vieille (the country's capital) and Escaldes-Engordany.

1.2 Road network and traffic



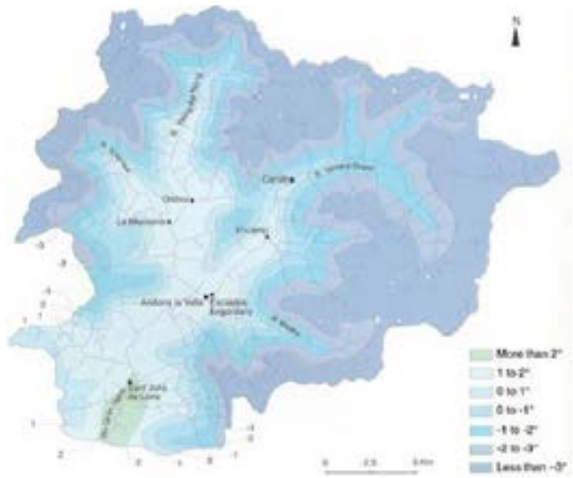
ACCESS ISOCHRONES FOR THE PRINCIPALITY

Connections to the outside are possible solely by road using either one of the two border-crossing roadways: towards Spain, across the border at the Runer River, at an altitude of approximately 800 meters and 140 km from the city of Lleida or 200 kilometers from Barcelona.Theconnection to France is more difficult, because the border is at Pas de la Casa, at an altitude of 2,000 meters, making circulation more difficult in the winter months. The closest French cities are Perpignan at 170 km and Toulouse at 190 km.

Slightly more than 40 km separate the Spanish border from the French border. This road goes through the capital, where the average traffic is around 100,000 vehicles per day. The other main road is that connecting Andorre la Vieille to the parish of Ordino. The rest of the road system is composed almost entirely of high mountain roads.

2. CLIMATE

2.1. OVERVIEW OF CLIMATIC AREAS



3- AVERAGE TEMPERATURES IN THE MONTH OF JANUARY IN ANDORRA (RASO, 1999)

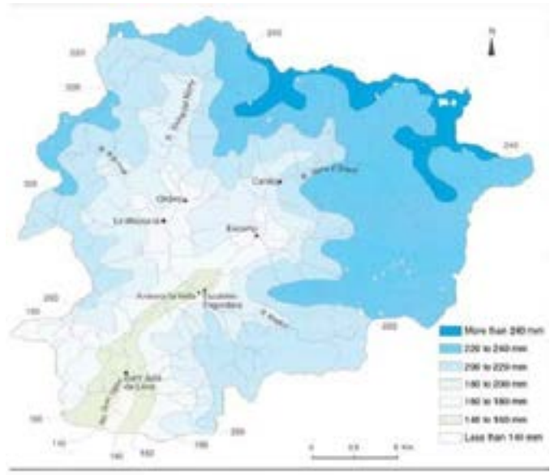
From a regional point of view, the Principality of Andorra can be said to fall within the sphere of the Mediterranean climate; however, a set of geographical factors influencing the climatic behavior in particular must be taken into Frist the relief and significant altidudinal clime present in the Principality of Andorra. Most of the country is at 2,000 m, and accordingly falls within the realm of mountain climates where precipitations are higher than in the valleys, temperatures lower, the temperature range greater, and the wind more present. From 2,000 – 2,200 m, snow is likely to fall on a regular basis from December to April. The situation changes in the warmest part of the year, especially summer, when the convective activity generates intensive precipitation, often in the form of storms lasting a short time.

The other important geographical factor to be taken into account is Andorra's distance from the sea. Proximity to the Atlantic Ocean fosters the inflow of wet winds from the French side of the Pyrenees. This characteristic leads to major precipitation in the form of snow in the winter season, particularly on the mountains in the mid-north part of the country. Andorra is under the influence of temperate climates (depending on precipitations), particularly in winter. These northern advections arrive with more difficulty in the southern half, which is more under the influence of the inflow of masses of humid air from the Mediterranean, and at a higher continental degree. Finally, it can be said that the climate in Andorra is defined by the following systems: Mountain – Mediterranean – Temperate

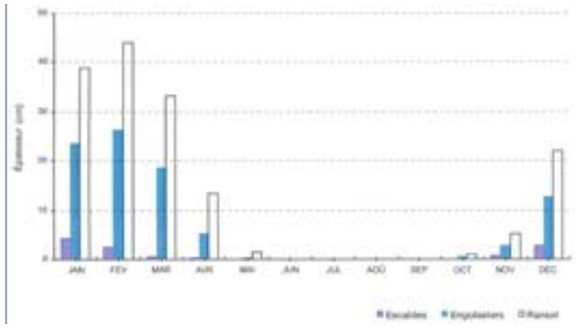
2.2. Noteworthy climatic data

In maps 3 and 4, which show the average figures for precipitations and temperatures during the annual cold period in Andorra, we can see that the northern and eastern sectors of the Principality are the areas where the highest probability of snow on the ground is concentrated.

Graphic 5 provides information on the months when there is more snow on the ground: particularly January, February and March.In conclusion, note that



4.- AVERAGE PRECIPITACIONS IN THE MONTH OF JANUARY IN ANDORRA (RASO, 1999)



5-MONTHLY DISTRIBUTION OF THE AVERAGE DEPTH OF SNOW IN ESCALDES (1,100 M), ENGOLASTERS (1,600 M / SUNNY) AND RANSOL (1,600 M / DARK) (RASO, 1999)

the maximum amounts of snowfall accumulated in 24 hours in the 1986-2003 period were 85 cm at 2,100 m (Pas de la Casa), 56 cm at 1,600 m (Ransol) and 40 cm at 1,100 m (Escaldes).

2.3 Winter indices used in the country

The Government, directly through its crews, is responsible for road maintenance and uses indices that are not based solely on weather conditions to indicate the difficulties caused by winter. Snowfalls during the winter in question and the quantities of salt used are the benchmarks for assessing the season's harshness.

3. Winter Road Management

3.1 STANDARDS AND RULES

6.- Graph of tones of salt per season

Classification of roads.

Roads are classified into two types:

• General roads, property of the Government;

• Secondary roads, which belong to local corporations, communes.

Legal obligation

As owner, the central government is obligated to oversee the general roads, which ensure circulation at the national level. According to legislation on the delimitation of powers, the government is also responsible for maintaining secondary roads.

Levels of service

In the winter, the Ministry of Land Management, determines the level of service based on two criteria: the functional classification of the road and the daily average traffic intensity (DAI).

Level of service	roads
Level of service 1: Road always clear	General roads and secondary roads with a high DAI
Level of service 2: Road always clear during the day and partially clear at night	Secondary roads

Removal with neigboring countris by assisting then in extreme situations. Twis was the case when Catalonia (Spain) saw m,ajor snowfalls in 1962 and 2001.

In terms of winter maintenance, all road maintenance is managed by government crews. Communal crews are responsible only for roads within agglomerations. However, the effective collaboration between

7.- COL D'ENVALIRA, 1960

the seven communes and the central government in this area should be noted.

Sectoral organization of snow removal

The sectoral division is based on the "Y" shape of the road system, which follows the valley floors. Based on the physical and climatic characteristics, winter maintenance (WM) crews were divided into three sectors:

• The North Valley Sector, with a network of 130 km of roads;

• The South Valley Sector, with a network of 70 km of roads;

• The East Valley Sector, which only has a network of 70 km, but which must make sure that the Col d'Envalira, at an altitude of 2,408 m, permanently remains open.

Staff labor program

The organization and work of the winter maintenance staff are planned according to the sector:

• In the North and in the South Valley , all of the staff works on call. The labor force was increased a few years ago to achieve the levels of service required, because in the case of continuous snowfalls (more than 2 days), we had trouble providing sufficient crews, particularly at night. Remember that these crews are responsible for clearing the only road connecting to Spain;

• In the East Valley d'Orient, a sector in which the connection to the French border must be ensured at an altitude of over 2,000 m, a different work method is employed. Near Col d'Envalira and the border, we have a work centre, strategically located, where snow removal

8 - SNOWPLOW

9 - SNOWPLOWER

staff are present from morning until evening every day of the week. At night, we have on- call staff that can be called depending on weather conditions.

Inspection and winter control

During the Winter Maintenance season, from November 1st to May 30, an inspection service covers all the roads. It focuses in particular on the most problematic areas. The mission of this service is to prevent the risk of morning frost on roads during the rush hour.

In the event of ice or snow, the inspectors notify the salt- ing or snow removal crews. Depending on the weather conditions, these teams monitor road conditions on an ongoing basis.

Snow removal equipment

The total number of snowplows in the Government's possessionis 20 units. These are also equipped with salt and brine spreaders

There are also salt/brine spreaders and snowblowers to clear those areas most affected by the snow

Avalanche prevention

A technical assistance service with experts in avalanche prevention is on alert for the duration of the winter season. In the Principality, 12 sites where avalanches can reach roads are monitored.

This surveillance is ensured by a third-party company and comprises three types of actions:

1. Monitoring the snow cover and weather forecasts during snowfalls

2. „Expert" estimates of a localized risk when the situ-

10. PROTECTIVE BARRIERS, SCREENS, NICOLAU CANAL, EL SERRAT.

ation requires it;

3. Avalanche control using avalanche cannons, Catex and Gazex.

3.3 Assessment of snow and ice control measures

Every year, all of the departments that take part in snow operations (government snow removal services, police department, traffic services and communal snow removal services) draw up an account of the season and work to make the necessary improvements in preparation for the next season. In our country's economy, there is a very strong link between winter maintenance, tourism and mobility, and the GDP. That is why it is important for all officers assigned to these strategic sectors to work together to provide the tools needed to make structural decisions.

11.- GAZEX EN LES FONTS, ARINSAL.

3.4 Road safety and information

Information system

The Mobility Agency, the department that oversees the National Traffic Centre (CENATRA), and the snow removal crews of the Road Operation and Conservation Service (COEX) are committed to promoting and disseminating advertising campaigns to raise users'awareness of responsible driving and the use of road vehicles in the event of snow. These initiatives were carried out in the form of the"les couleurs de la neige" [the colors of snow] campaign

12-VARIABLE MESSAGE SIGN

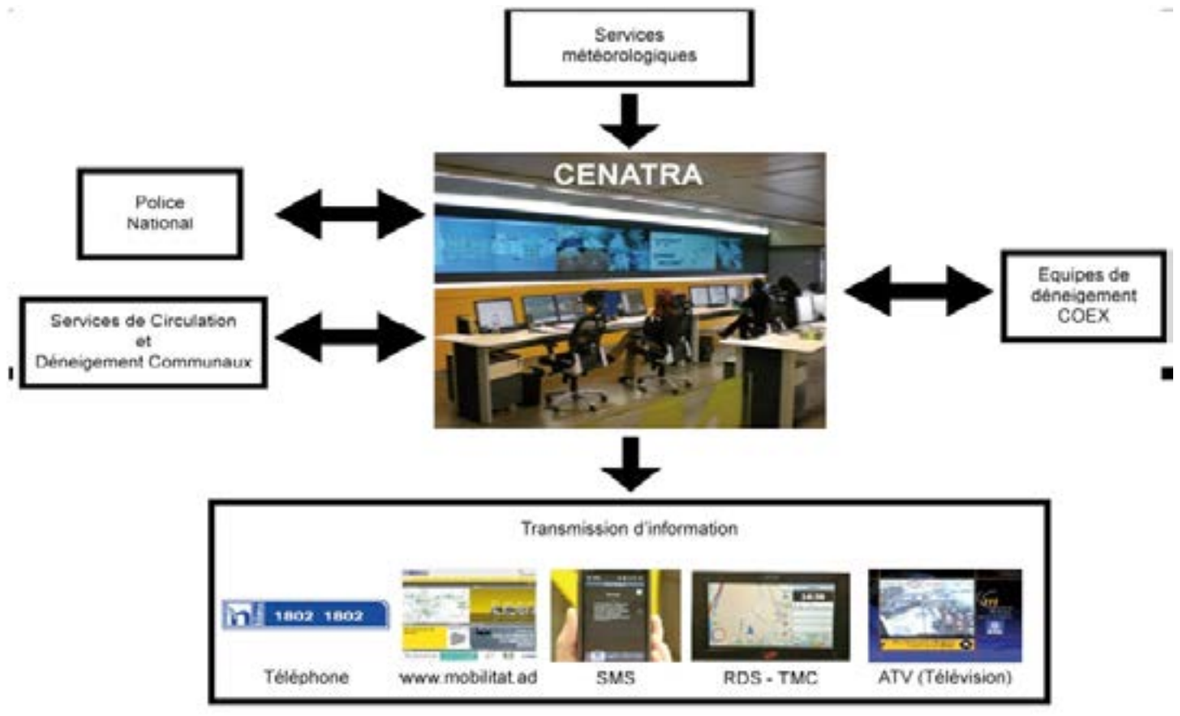
Information is crucial in winter maintenance management. A communication infrastructure, based in CENATRA, was established. On the one hand, the road inspection and monitoring crews of the Road Conservation and Operation Service (COEX) notify the National Traffic Centre (CENATRA) of incidents, with constant feedback between the National Police and the communal traffic and snow removal services. On the other hand, using variable message signs and the media (text messaging, web services, RDS-TMC, radio bulletins, etc.), CENATRA provides information regarding road conditions

4. ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 New technologies

Ongoing projects:

GREEN STARTING TO SNOW	YELLOW SNOW ON THE ROAD	RED ROAD COVERED WITH SNOW	BLACK ROAD IMPASSABLE
• Traffic is undisturbed. • Take more care. • Do not exceed a speed of 80 km/h. Stay attentive to weather changes. Drive with care in wet areas and on clear nights because of the possibility of frost.	• Use of chains or special tires at a maximum speed of 60 km/h. • It is recommended that trucks and articulated vehicles not be operated. Slow down, particularly in turns and on banked roads. Avoid all unexpected maneuvers and increase your safety headway. Do not continue travelling if the weather starts to deteriorate and you have no special equipment (chains, warm clothes, etc.).	• Use of chains or special tires at a maximum speed of 30 km/h • Use of chains mandatory on busses. • The use of freight transportation vehicles with an authorized average weight of over 3,500 kg is forbidden. Unless absolutely necessary, it is preferable to postpone the trip. Do not stop the car on a hill or in places where you would be hindering traffic. Do not pass stopped vehicles if you are not sure you will be able to keep going.	• Risk of being immobilized on the road for a long time. In the event of immobilization, conserve fuel and abandon the vehicle only if you are certain of finding shelter. Do not leave the car in places where it might become an obstacle to snowplows.



• On-board communications equipment (TETRA system) for real-time data on the exact position of all snow removal vehicles and to obtain data from sensors analyzing the working conditions for each vehicle;

• Automatic laser stations on salt-spreading vehicles with relative humidity, surface temperature and air temperature measurement to calculate the exact rate of salt and brine;

ANDORRA

• Road frost sensors;
Generalization of the use of brine
14- Brine production station

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ARGENTINA

At the institutional level, Argentina is a democratic and federal republic consisting of 23 provinces and the Autonomous City of Buenos Aires. It has an executive political system made up of a president and provincial governors, national and provincial legislative systems and an independent judicial system with national and provincial jurisdictions.

The Argentine territory is located in the Southern Hemisphere in relation to the Equator, and in the Western Hemisphere when taking the Greenwich meridian as a reference.

In terms of area, Argentina has the second largest territory in South America after Brazil, and the second largest in Latin America. It has the fourth largest territory in all of the Americas and the eighth largest in the world. It borders Chile, Bolivia, Paraguay, Brazil and Uruguay. Argentina's geography is highly varied, with mostly plains in the east, hilly country in the centre and mountains in the west. On its western side, the country is traversed from north to south by the Andean Cordillera [mountain range], which essentially marks the border with Chile. The highest peak in Argentina is Aconcagua, at 6,960.8 MASL.

Argentina's actual sovereign area covers a broad band of latitude: there are 3,779 kilometres between its northernmost and southernmost points, La Quiaca to Ushuaia, making Argentina one of the longest countries in the world.

The Argentine continental area is 2,791,810 km^2. This includes 2,780,400 km^2 corresponding to the Federal Capital (Autonomous City of Buenos Aires) and the 23 Argentine provinces. The rest is made up of the 11,410 km^2 of the Falkland Islands. In turn, the Antarctic continental area includes 969,464 km^2. Of those, some 965,597 km^2 correspond to the Argentine Antarctic (reclaimed territory). This area also includes the South Shetland Islands and the South Orkney Islands. The remaining 3,867 km^2 are formed by the South Georgia Islands (3,560 km^2) and the South Sandwich Islands (307 km^2), which are part of the South Atlantic Islands Department of the province of Tierra del Fuego, Antarctica and the South Atlantic Islands, as well as the Antarctic sector (included as a department). Argentina's total territory is therefore 3,761,274 km^2.

POPULATION

Argentina has a population of 43,847,430, with females making up the majority—22,389,000 females, or 51.06% of the total population, as compared to 21,458,430 males, or 48.94%.

Argentina can be considered a country with a significant number of inhabitants, when compared to other countries—it is ranked 32nd among the 196 states that compose the world's population. Immigrants account for 4.81% of Argentina's total population, although much of its population in the last century and a half was made up of immigrants from different regions of the world. Argentina currently ranks 82nd in the world for percentage of immigration.

The composition of the current Argentine population is strongly influenced by the tidal wave of immigration that occurred between 1870 and 1930, which in particular saw an influx from Europe, the Near and Middle East and Japan. Other immigrants were indigenous peoples, Asians (from the Near, Middle and Far East) and Africans (brought as slaves to the territory of present-day Argentina).

Argentina is regarded as a "country of immigration" due to the massive migratory flows that it has received over time, mainly from Europe and primarily including Italians, Spaniards, Germans and Poles. Current immigrants are coming from Asia (China and South Korea) and from a large number of neighbo-

uring South American countries, notably Paraguay, Bolivia, Peru and, to a lesser extent, Colombia, Chile, Uruguay, Brazil and Venezuela.

Although Argentina is one of the largest countries in the world, it has a very low population density, with 16 inhabitants per square kilometre, although that figure varies widely between regions.

Population density

- *Fewer than 1.0 inhabitants/km²*
- *1.0-4.99 inhabitants/km²*
- *5.0-9.99 inhabitants/km²*
- *10.0-19.99 inhabitants/km²*
- *20.0-39.9 inhabitants/km²*
- *Over 40 inhabitants/km²*
- *City of Buenos Aires: 14,455.4 inhabitants/km²*

In opposition to the above-mentioned low population density, there is a population concentration in the greater Buenos Aires agglomeration (38.9%), which also has a high proportion of persons over 60 years of age (14.3%). It has high life expectancy (75.3 years) and literacy (98.1%) rates.

If the Buenos Aires agglomeration is added to the province of Buenos Aires and the population located in the axis of the agglomeration and the city of Rosario (a vital river port), almost 50% of the Argentine population is located within less than 10% of the territory.

Geographic location

To the north, Argentina is bordered by Bolivia, with a fixed border made up of the Cochinoca mountain range; the Grande de San Juan, Bermejo, Grande de Tarija, Itaú and Pilcomayo rivers; and Paraguay, from which it is separated by the Pilcomayo, Paraguay and Paraná rivers.

To the east, it is bordered by Brazil (Iguazú, San Antonio, Pepirí Guazú and Uruguay rivers), and Uruguay, in the form of the river by the same name, and the La Plata River.

To the west, it is bordered by Chile, with the Andean Cordillera essentially comprising the common border. Argentina's southern borders were defined in a 1984 treaty on the Beagle Channel and Drake Passage, which link the Atlantic and Pacific oceans and which in turn form the southernmost point to which Argentina's effective sovereignty extends.

Argentina extends from 33° latitude at its northernmost point to 21°46'S; its southernmost point on Isla Grande of Tierra del Fuego is at 55°03'51"S. It extends from west to east across 20° of longitude, from a point southwest of the Patagonian Andes in the province of Santa Cruz at 73°38'W, to the town of Bernardo de Irigoyen in the province of Misiones, at 53°35'W.

Regions

Argentina has many geographic regions. Its formal regions are:

- Northeast region, which includes a zone known as the Altiplano [high plateau]
- Pampas mountains
- Cuyo
- La Plata River plains

- *Subtropical with no dry season*
- *Subtropical with dry season*
- *Tropical highland*
- *Temperate and humid Pampean*
- *Temperate and semi-arid Pampean*
- *Temperate oceanic*
- *Temperate highland*
- *Arid hills and fields*
- *Semi-arid*
- *Patagonian arid*
- *Andean-Puna arid*
- *Humid and cold*
- *Antarctic cold*

- Subtropical plateau
- Patagonia
- Argentine Antarctic

Argentina's natural resources are abundant. The Pampas (part of the La Plata River plains) are suited to growing grains and oilseeds, as well as to livestock farming. Patagonia is rich in oil and gas, as well as fish species. A variety of minerals, such as uranium, silver, gold, lithium, etc. can be found in the pre-Cordillera region.

Climate

Given its vast territory, as well as its range of latitudes and altitudes, Argentina has a wide variety of climates. Generally speaking, since the Southern Cone is surrounded by enormous oceanic masses, there is less variation between summer and winter as compared to numerous regions at middle latitudes in the Northern Hemisphere.

Argentina has two rainfall patterns: Atlantic and Pacific. The first penetrates from the east and northeast and covers most of the northern and central parts of the country. Due to its greater penetration in summer, there is higher rainfall in that season. The Pacific pattern comes from the west and produces precipitation in the Cordillera and Patagonia, mainly in winter. As the Andes act as a barrier, precipitation is very low on their eastern slopes. In the same way, there is also little rain in the vast expanse of land that separates the northwest and Cuyo regions from the Atlantic. Therefore we can speak of two main foci of precipitation: one that moves from the northeast, with precipitation exceeding 1500 mm in Misiones, and another from west Patagonia with precipitation reaching 3000 mm in southwest Neuquén. Beginning in the province of Misiones, the precipitation gradually decreases towards the west and south, with values of about 1000 mm even in north Buenos Aires and central Chaco. In Neuquén, due to the barrier caused by the Cordillera, a few kilometres east, precipitation is less than 300 mm. A third focus of rainfall occurs in the sub-Andean zone in the north, where the winds from the east collide with the mountains and discharge about 1000 mm annually in a thin strip (home to the provincial capitals of Jujuy, Salta, and Tucumán), which is much more than in the neighbouring regions. These rains

Biomes

- *Misiones jungle*
- *Mesopotamian parklands*
- *Chacoan parklands*
- *Tucumano-Salteña jungle*
- *Andean-Puna steppe*
- *Mountain*
- *Pampean steppe*
- *Patagonian steppe*
- *Patagonian Andes-Tierra del Fuego forest*
- *Southern province and Antarctica*

are also strongly seasonal, appearing during the summer.

In general, since vast portions of Argentina are located at intermediate latitudes, and at altitudes close to sea level, different Pampean-type temperate climates predominate, which are highly suited to human life as well as to the agricultural development on which the country's economy is based.

The winter cold intensifies with increased latitude. The lowest temperatures in South America at low altitudes (-33°C) are found on the Patagonian plateau. In the Tierra del Fuego archipelago, temperatures are cold year-round, although the intensity of winters is weakened by the temperate effect caused by the huge southern ocean masses. The cold likewise increases at higher altitudes, and is especially noted in the country's northwest and west-central parts, coinciding with the presence there of Andean Cordillera plateaus and ranges of significant height.

This means that every winter, the roads that cross the Andean chain toward Chile are prone to traffic disruptions for several weeks due to heavy snowfall, although the latter is a boon to the tourist industry based on winter sports.

There are few zones in the country where snow has never fallen; however, rain is very rare in the northeast Chaco-Pampean plain and the northern coast of the province of Buenos Aires, and even more rare in Greater Buenos Aires, whose winters are tempered by the moderating action of the La Plata River and of the heat island effect that develops in the megalopolis (which also makes frost rare). Snowfalls are more frequent towards the west, as the altitude increases, and towards the south. Their annual period of occurrence and intensity also increases, to the point that on the shores of Tierra del Fuego's Beagle Channel, snowfalls in some years can occur even in midsummer.

The seasonal pattern of rains is another noteworthy climate fact in Argentina. Much of Patagonia has a Mediterranean climate with rains that fall during the winter, with notably less rainfall in the summer. By contrast, in the northwest and in the entire Chaco region, the opposite is true. There, the climate is monsoon, with abundant summer rain and decidedly dry winters. In the country's east, both in Mesopotamia and in the humid Pampa, there is also less winter precipitation, but the differences with the remaining seasons is not as marked.

The winds vary significantly in intensity in the different regions of the Republic; they are very mild in some parts of the northwest and very intense and constant throughout Patagonia (blowing from the south and southwest). However, these winds can also be productively used to generate electricity. Some regions have characteristic winds; for example, the Zonda wind in Cuyo, which blows hot and dry from the west; the cold, dry and intense Pampas wind that sweeps clouds and moisture onto the Pampean plains; and the strong southeasterly winds that bring cold, humid and rainy days by raising the La Plata River's water levels. Argentina's climate has been monitored and studied for over a century by the National Meteorological Service (SMN).

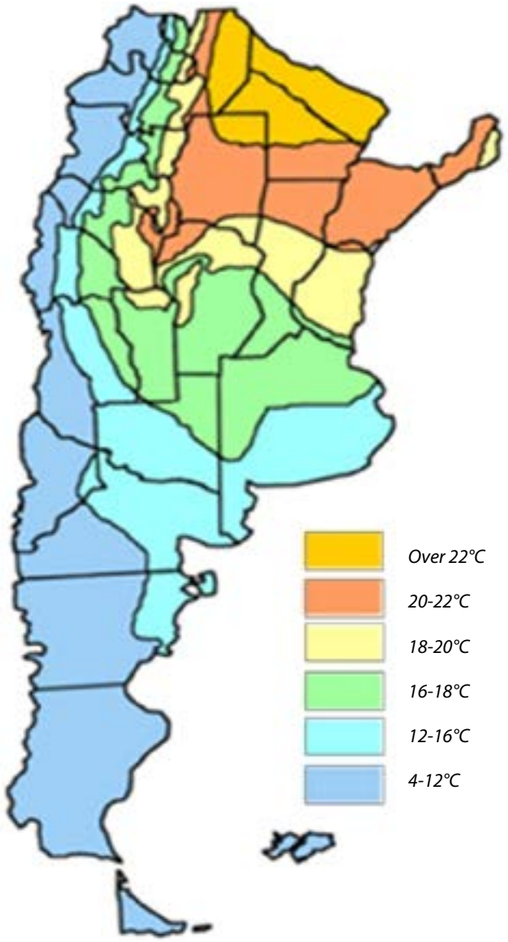
Seasonal pattern

Although Argentina's climate tends to be simplified as "hot" in the north, "temperate" in the centre and "cold" in the south, there are four seasons in practically all of Argentina, although the higher average temperatures are obviously in the north (e.g., in the Tropic of Capricorn area), and much lower average temperatures are found in the south (zone of influence of the Antarctic Circle). Given these latitudinal differences, the altitudinal cooling throughout the elevated region of Argentina is unique, most notably to the west of the Pampas Mountains. It is very noticeable in the high altitudes of the great Andean Cordillera.

It should be noted that since all of Argentina's territory falls within the Southern Hemisphere, the cycle of seasons is symmetrically inverse and complementary to the Northern Hemisphere's seasons; i.e., when summer starts in Argentina, winter starts in Europe, the United States, China, Japan, etc., and vice versa. When winter starts in the Northern Hemisphere, summer begins in almost all of South America, parts of Africa, Oceania, and all of the Antarctic.

Likewise, the sunny slopes in Argentina tend to be on the north-facing Cordillera, while shade is found on the south-facing slopes or mountainsides of the Cordillera.

It is also worth noting that Argentina, together with Chile, all of Uruguay, the southern region of Brazil, southern Australia and all of New Zealand are the only continental and island territories of the Southern Hemisphere with four well-differentiated seasons (similar to what occurs in Europe and the United States).



AVERAGE TEMPERATURES IN THE AMERICAN SECTOR OF ARGENTINA

Regions affected by winter phenomena

In addition to short-lived phenomena, there are regions and subregions affected by winter phenomena. One such region is affected by the high summits of the Andean Cordillera that are found in seven provinces and that have mountain villages and international passes linking them with Chile that are affected by these phenomena.

The other region is Patagonia, which consists of five provinces that have lower mountainous zones than the northern zone of the Andean Cordillera; however, they coexist with non-mountainous zones with low

temperatures and snowfall that affect movement and production in those zones.

Patagonian region dominated by snowfall and cold

The Patagonian region of Argentina is climatically subdivided (not including microclimates) into two major regions—the Andean Patagonia west of the Andean Cordillera and the Patagonian mountain range, and the southern third of the island of Tierra del Fuego—in a cold and perihumid (2,000 mm annually) climate zone that allows dense tree vegetation to thrive. However, about 50 km east, the precipitation gradient abruptly decreases to less than 500 mm per year because of the effect of the Andean Cordillera, since much of the moisture carried by the winds blowing from the southwest quadrant condenses and precipitates in the form of snow (especially from April until early October) and then in the form of rain in the Patagonian Andes Cordillera. Therefore, the climate of Extra-Andean eastern Patagonia tends to be semi-arid or fully arid, though with wide temperature ranges and frigid winters which, in the southern winter, can cause intense precipitation and temperatures averaging about -40°C.

In the arid steppe climate of northern Patagonia, annual average temperatures are under 15°C, and there is very frequent frost and little precipitation (400 mm per year). However, precipitation increases in the northwest corner of the Patagonian Cordillera and is more abundant during the winter. In southern Patagonia, the climate is very cold. The average temperature is below 5°C and precipitation measures 300 mm; and on the Patagonian coast, temperatures in some summers can be high.

Precipitation is about 2000 mm and up to 4000 mm along the border with Chile, and falls abruptly to the east to 200 mm. Winter snowfalls are frequent.

Patagonia begins south of the Colorado River, with its plateaus gradually descending from 1500 to 2000 metres in height in the Andean foothills to a seacoast with rugged cliffs and broad inlets (gulfs of San Matías and San Jorge, Bahía Grande, the Valdés peninsula, Cape Three Points, etc.). Deep canyons cut through these Patagonian plateaus and through them flow the rivers coming from the Andean Cordillera.

A characteristic feature of western Argentina is the presence of the Andean Cordillera.

The Andean Cordillera extends over 7500 km, from Venezuela to Tierra del Fuego. It is characterized by its high altitude, grandeur and width in Bolivia and by the strength with which it rises above the Pacific to the west and over the Central Plains to the east. Various sectors with different characteristics can be distinguished in the geography of the Andes.

Andean Cordillera region

The Andean Cordillera is the chain of mountains found in the western part of South America. It covers an approximate area of 3,370,794 square kilometres and lines 7240 km of the Pacific and part of the Caribbean Sea coast, making it the longest mountain range in the world. The Andes fall between 11°N and 55°S latitude, and form part of the territories of Argentina, Chile, Bolivia, Peru, Ecuador, Colombia and Venezuela. They are home to the highest volcanoes on the planet. At their southern end, the Andes sink into the Atlantic Ocean east of the Isla de los Estados (an island that lies off the Argentine portion of Isla Grande de Tierra del Fuego).

In their southern part, the Andes act as a natural border between Argentina and Chile; the highest mountains on the continent are found there.

The highest summit of the Andean Cordillera is Aconcagua (6,960.8 MASL), which is also the highest altitude in the Southern and Western hemispheres. It is located in Mendoza, Argentina.

Argentina and Chile share the highest peaks of the Andes; these include the Nevado Ojos del Salado, the highest volcano in the world and the second highest summit on the continent. Of the 10 highest volcanoes on the planet, six are shared by Argentina and Chile, three are in Argentina and one is in Bolivia.

Argentina's relief is fundamentally determined by the strong opposition between the great plains to the east and the Andean Cordillera to the west.

Extending longitudinally from north to south along the border with Chile, Argentina's relief in the Andean region offers a variety of features. At the northern end, we find Atacama, a vast desert plateau at 4000 m altitude that crosses through mountains exceeding 5,000 metres, and that has numerous enclosed depressions known as salt flats. This impressive desert dominated by volcanoes such as Llullaillaco at 6,723 metres high, and shared with Chile, loses height towards the south to give way to older and more uniform mountain ranges traversed by narrow valleys known as quebradas [ravines] that serve as natural passes between the two countries. The largest is the Quebrada de Humahuaca. In their central part, the Andes break into short, solid chains divided by arid depressions. As it moves towards 36° latitude, the Cordillera again loses height.

Argentina's highway network

As stated above, Argentina is a federal country made up of 23 provinces and an autonomous city. Its highway system is therefore centrally composed of a national network of roads administered by the National Roads Directorate and a system of provincial networks administered by the provincial roads directorates of each of the provinces.

At the national level, the functional objectives are to unite all the provinces and production zones, ports and urban conglomerations, and to achieve territorial organization of the country. In the case of the provincial networks, the functional objective is internal communication between the various cities and production centres and social organization of the territory.

Although its population is concentrated in a relatively small area of its territory, and most productive activity takes place in the central region of the country, Argentina has, over time, built an integrated highway network. The development of the network has been balanced throughout the country, which allows for a significant level of integration, although there is a lack of paving, especially in the provincial networks.

	National network	Provincial networks	Total
Paved	36,235	44,861	81,096
Gravel	2,764	39,234	41,998
Dirt	1,040	114,193	115,233
Total	40,039	198,288	238,327

The national network consists of 40,039 km, 90% of which are paved, and 2800 km of which are freeways and highways. For their part, the provincial network and roads cover 198,288 km; just 44,861 [km], or 23%, are paved.

Winter road management

In this territorial and climatic context, there are centralized national road management activities as well as provincial and municipal management to address such situations. Given that the border with Chile is the Andean Cordillera, it is a national policy to jointly develop an integrated system of border crossings with Chile. At present, there are 26 prioritized border crossings, not including the many others that serve the development between border towns in the two countries.

In general, all these crossings are affected by winter driving phenomena.

The winter road management system is subdivided into different classes:

- Border crossing systems with Chile
- High-mountain road maintenance systems
- Status of roadways subject to winter effects
- Urban and peri-urban systems affected by winter driving phenomena

Border crossings systems with Chile

Although different crossings through the Andean Cordillera have been developed over time for different border-related and political reasons, systematization of their management began in the 90s.

In 1996, agreed-upon and prioritized border crossings with Chile numbered thirteen (13), of which twelve (12) were on national roads. In those days, the Cristo Redentor pass on the RN 7 was the only one whose daily operations included winter management activities.

At present, there are twenty-six (26) border crossings with Chile that have been prioritized by both countries. Of those, fourteen (14) are on national routes (1,300 km) and twelve (12) are part of provincial networks (280 km).

Of the 26 crossings, 9 are paved on the Argentine side and 8 are paved on the Chilean side.

Years ago, the National Roads Directorate participated in four (4) WWGs (winter working groups) on instructions of the Chile-Argentina MWG (Mixed Working Group) that coordinates the joint operational activities.

Each year, the four WWGs—north, central, south and austral—develop the WOPs (winter operating plans) for the prioritized crossings, including the resources to be committed. Given the distinct climatic realities with respect to winter driving, as well as traffic and infrastructure drawbacks, these four groups have been established to address winter problems.

Based on the operations involving joint policies with the Republic of Chile, service levels are determined that essentially include prior warning of winter events, network clearing activity, and a human and material resources planning policy.

In some cases, the passes are high-mountain ones; others are between border towns in the two countries.

A highlight among these passes is the Cristo Redentor System, a Mercosur transportation connection that is a bi-oceanic system, since it is the most-used means of travelling from São Paulo, Brazil; Montevideo, Uruguay; and the central areas of Argentina both for interregional trade and for travelling overland between the Atlantic and Pacific oceans.

Given its importance to both countries, the functioning of this pass is fundamental to trade and to the movement of people in the winter.

Border crossings

Name	Height (MASL)	Surface
Jama	4,200	Paved
Sico	4,092	Gravel
San Francisco	4,726	Paved
Pircas Negras	4,160	Gravel
Agua Negra	4,780	Paved
Cristo Redentor	3,186	Paved
Las Leñas	2,570	Dirt
Pehuenche	2,553	Paved
Pichachén	2,060	Gravel
Pino Hachado	1,884	Paved
Icalma	1,298	Gravel
Mamuil Malal	1,253	Gravel
Carirriñe	1,223	Gravel
Hua-Hum	625	Gravel
Cardenal Samoré	1,305	Paved
Río Manso	350	Gravel
Futaleufú	335	Gravel
Coyhaiqué Alto	728	Gravel
Huemules	650	Gravel
Ibáñez	327	Gravel
Jeinemeni	305	Paved
Mayer	270	Dirt
Don Guillermo	260	Gravel
Laurita Casas Viejas	90	Gravel
Austral integration	164	Paved
San Sebastián	20	Gravel

In this regard, Argentina, Brazil and Uruguay have developed major ports on the Atlantic Ocean, and Chile has built significant port infrastructure on the Pacific Ocean.

For this reason, in addition to the commitments to forecasting, warning and clearing of the corridor, Argentina has developed a winter system to address the huge challenges posed by winter in the zone.

The Cristo Redentor pass links the Argentine Republic to the Republic of Chile and is the main commercial throughway to the Pacific Ocean. The corridor also serves significant vehicle traffic coming from the Republics of Uruguay, Brazil, Bolivia, Peru and Paraguay.

The crossing is done through a 3-km-long tunnel that sits at an altitude of 3200 MASL. Winter conditions generally affect the road as of 2000 MASL, with a resulting impact on five villages: Uspallata, Polvaredas, Punta de Vacas, Puente del Inca and Las Cuevas. Along the route, there are two ski resorts and various winter recreation centres.

International traffic is approximately 2800 vehicles per day. In July 2016, during the winter vacation period, traffic exceeded 100,000 local vehicles, in addition to 85,000 international-traffic vehicles.

Infrastructure:

The Cristo Redentor Andean Corridor has:

- A main camp in Uspallata. 2,080 MASL
- Three high-mountain camps:
  - Punta de Vacas at 2,400 MASL
  - Puenta del Inca at 2,700 MASL
  - Las Cuevas at 3,200 MASL
- Two subcamps:
  - Potrerillos at 1,380 MASL
  - Polvaredas at 2,400 MASL

Operations

The functioning of the corridor, in terms of whether it is open or closed, is managed by the authorities of the National Gendarmerie of Argentina and the Carabineros of Chile, which coordinate the information on which the functioning of this important pass between the countries depends.

In addition, Chilean and Argentinean road technicians maintain ongoing contact under the framework of the action plans set out in the Winter Operating Plans, with activities scheduled for their territories and a cooperation system with respect to materiel, personnel and equipment for emergencies throughout the Corridor.

The above-mentioned camps and subcamps maintain the equipment for clearing and improving the corridor, which includes snowplows, frontloaders, motor graders and all [forms of] winter equipment. It should be noted that in recent years, there has been a re-equipping of all the machinery for servicing the corridor, and new equipment is constantly added to meet the operational needs.

Winter road management operations in this corridor are based on five pillars:

- Meteorology
- Telecommunications infrastructure (Internet, information and real-time images)
- Transit maintenance and rehabilitation strategies
- Communication with other organizations and services
- User information

In terms of meteorology, a network of weather stations has been installed that belongs to the National Roads Directorate. This helps capture information by using a set of globalized models for detecting winter phenomena. In addition, local and regional forecasts are analyzed and loaded into a database so that the available information can be analyzed and the operations to be carried out can be planned. This assists the operational personnel with the corresponding decision-making.

This has involved gradual improvements to the telecommunications infrastructure to enable real-time communications and image capture.

With respect to Transit Maintenance and Rehabilitation Strategies, a set of activities are carried out that are central to winter road management operations. These can be summarized as:

- Routine work – assorted preservation work
- Preventive work (proactive)
- Work during storms
- Post-storm work (reactive)
- Removal of rocks or dense items
- Passive avalanche control
- Snow fences
- Optimal use of equipment and other resources

A roadworks system to modify the corridor's infrastructure is also scheduled for the coming years. It will involve widening of roadways, new tunnels, snow sheds, and roadworks aimed at preventing accidents caused by winter phenomena.

Accumulated precipitation during snowfall at road level (mm)	Equivalent height of snow (m)	Fresh-snow avalanche occurrences
30-50	0.3-0.5	Small avalanches occur during storms in some sectors between Puente del Inca and the border. The roadway is not affected.
50-150	0.5-1.5	Avalanches occur during storms between Punta de Vacas and the border. They reach the edge of the roadway between Punta de Vacas and Puente del Inca and moderately affect the roadway between Puente del Linca and the border.
150-250	1.5-2.5	Avalanches are produced during and after storms (in the first 24 hours) and affect the roadway from Punta de Vacas to the border with a significant impact on the road.

With respect to de-icing work, the pass has three de-icing solution preparation plants, which use mixtures of sodium chloride (NaCl), calcium chloride (CaCl2), and cane vinasse (agricultural fertilizer).

There are areas of recurrent avalanche production in the corridor, and preventive measures are being developed in conjunction with research institutes in those zones to prevent uncontrolled avalanches from occurring. There are therefore passive control actions for avalanches, as well as active actions, such as the construction of a set of fences.

This corridor has 32 machines used for work on its roads. Optimal use must therefore be made of the equipment.

For operational purposes, the equipment is classified as used for:

- Preventive work (before storms)
- Major snow-clearing work
- Minor snow-clearing work

Interactions with Other Organizations and Services are vital because they allow for ongoing coordination of information and plans.

The operations and coordination are rounded out with the development of an information network in the form of issuance of passability reports and user information through a National Roads Web page, as well as ongoing information via the mass media.

All of this helps provide users with the most reliable information on the status of and outlook for passability throughout the Corridor.

Given the high volume of road traffic in the Corridor, from the point of view of winter road management, it is the main focus for the development of winter operations in Argentina.

The other major crossings that are alternatives to the Cristo Redentor pass, but that also have significant traffic and commercial relations are the Cardenal Samoré pass between the province of Neuquén in Argentina and Osorno in Chile, which is a paved pass situated at over 1300 MASL, and which links a vast Patagonian region. For orographic reasons, in addition to regional trade, this pass is used by Chilean vehicles in domestic transit through that country.

There, in the context of the winter operations plans, ongoing coordination is taking place between control and technical authorities from both countries, with levels of action similar to those referred to in the Cristo Redentor System, since this pass is the second most important pass in the Cordillera crossings system.

The same is true of the so-called austral integration pass, which is unique in that it not only links Argentina and Chile without crossing the Magellan Strait, but also, in Chilean territory, it is the link between continental Argentina and Isla Grande, which is home to both Argentine and Chilean sovereign territories.

In the country's north, the other major pass is the Jama pass that links the province of Jujuy in Argentina to San Pedro de Atacama in Chile. This pass, at 4,200 MASL in the low-moisture area of La Puna, receives traffic from Argentina and Chile as well as Paraguay, Brazil and Peru.

In some brief periods there are road closures due to winter events, which require compliance with the operating plans to prevent closure of the pass. This pass is also an alternative to the central passes during very severe winters. Even though it is not permanent throughout the winter, it requires effective road-clearing equipment.

In the remaining passes, there is preventive and snow-removal work, but since there is less traffic, the road-clearing parameters are less stringent than in the four main passes of the system.

At present, the basic equipment for servicing the border pass system is as follows, with significant re-equipping scheduled for 2017-2018.

Passes	Allocated equipment
Coyhaique	3
Huemules	6
Don Guillermo	3
Dorotea	3
Laurita-Casas Viejas	3
Monte Aymond	8
San Sebastian	24
Rio Encuentro	3
Futaleufu	7
Cardenal Samore	16
Huahum	3
Carirrine	0
Mamuilmalal	4
Icalma	4
Pino Hachado	8
Pichachén	0
Cristo Redentor	23
Jama	13
Sico	6
San Francisco	10
Pircas Negras	8
Total	**155**

High-mountain road care systems

In addition to the roads linked to the border crossings system, there are national and provincial roads known as high-mountain roads that, due to existing populations or different types of production, whether agriculture/livestock or mining, must be kept in driveable condition.

For this purpose, the Provincial Roads Directorates have emergency equipment and personnel that take winter environmental phenomena into account.

The prevention system involves warnings to villages or establishments in the zone, together with reports from the National Meteorological Service, and activities are carried out based on general and province-specific protocols.

Status of roads affected by winter phenomena

While this sector is related to the two previous ones, snowfall or icy roadway situations can occur on roads that are not part of the passes system or high-mountain roadways.

It should be pointed out that the length of roads affected by winter phenomena, most of which are in the country's southern part, is estimated at 6,400 km.

Part of the activities are carried out by the National Roads Directorate, in some cases with its own equipment (2,300 km), and the remaining work is done using different means of third-party contracting.

As can be seen in the chart, there are various forms of winter road management operations.

Some operations are performed with [the Roads Directorate's] own equipment and personnel, and others through a transfer of operating functions (TOF) to the provinces and to other systems such as Crema and Modular through the contracting of companies under a results-based control system. Beginning in 1990, winter maintenance, mainly in the country's south, was through agreements with the provinces under the Transfer of Operating Functions method, in which driveability conditions and the corresponding measurements and payments are established.

This allowed for a framework of streamlined use of equipment, since some areas have both national and provincial roads, and it would not make sense to have separate emergency equipment.

Information and experience can also be exchanged between the various network operators.

In summary, in the total national road network, there are 1,300 km of border passes and 6400 km in the rest of the network—a total national network of 7,700 km—on which winter road management activities are carried out, or 19% of the network. Some 400 pieces of equipment and mobile [sic: poss. "mobile equipment units"] for winter road management are allocated to those sections and percentage.

Winter road maintenance in the national network

Management	Total km
Administration	2354
Modular system	21
CREMA	1487
Service contract	409
TOF	1876
On-site	173
Total	6320

The growing importance of winter road management within the network maintenance and driveability strategy is rounded out with the work of purchasing new equipment for these purposes. In this regard, a significant acquisition of equipment is forecast for 2017-2018.

Acquisition of equipment, 2017-2018

Motor grader, 200 HP	53
Front loader, 190 HP, 3m3	21
230 CV 7m3 flatbed truck with rear dump, Front loader, 190 HP, 3m3	52
Pneumatic tractor 160 HP, 4x4 traction	54
Skid steer mini loader, 80 HP	22
Smooth drum combination vibratory compactor	7
Crawler-mounted backhoe 21-tonne, 140 HP	5
Front loader with backhoe, 90 HP	15
Crawler-mounted tractor with bulldozer and ripper, 190 HP	5
6x4 truck tractor, 420 HP	6
35-tonne capacity flatbed trailer	5
4-person mobile homes	5
Horizontal road-marking equipment, cold	1
Horizontal road-marking equipment, warm	3
Truck with full pothole equipment	3
Crack sealer	10
Total equipment	**270**

Urban and peri-urban systems requiring winter road management

As with any network, winter climatic phenomena affect not only interurban linkage zones but also urban areas in some zones, which causes untold problems in people's daily lives.

In this regard, we must distinguish between urban sectors with the potential for climatic phenomena, which are generally rare, and those that see more of a daily effect in the winter.

In areas with a potential for effects on urban areas, the municipal and provincial authorities generally have a user information system for such events and a system for clearing the affected avenues and streets with their own equipment.

In the northern part of the country, this is the case in towns that service high-mountain roads.

From the province of Mendoza (zone of the Cristo Redentor Corridor) towards the south, there are many towns and cities regularly affected by winter phenomena.

In general terms, the provinces and municipalities designate equipment and personnel who are trained for such emergencies, and in the major cities, they have equipment ready for service throughout the winter. Cities such as San Rafael and Malargüe, in the province of Mendoza; and Chos Malal, Las Lajas, Zapala, San Martin de los Andes and Villa La Angostura in the province of Neuquén, have winter operating plans and protocols for clearing streets and roads in the least time possible.

Part of this zone falls within the National Parks Area of Patagonia, and a cooperation program is in place between all the official divisions.

Major cities such as San Carlos de Bariloche, El Bolsón and Esquel, among others, require and have a winter operating system and a street cleaning and clearing service.

Further south, a set of towns in the Patagonian Cordillera requires ongoing maintenance in the winter, and in this case, the provinces of Chubut and Santa Cruz have put together an operating system to support road-clearing in these cities, with additional equipment from the municipalities themselves.

The same situation is found in major cities such as El Calafate and Rio Turbio, which have high urban development and populations, and hence a need for ongoing clearing of ice and snow.

There, together with the provinces, the cities carry out the more-developed scheduled activity with clearing, use of salt and urea and equipment that prevents disruptions to daily life despite the low temperatures.

CONCLUSION

Winter phenomena affect part of the territory, generating problems in the international passes system, on high-mountain roadways, on roadways in the country's south and in certain cities also located in the country's southern part, especially in the Cordillera area.

As part of the road networks management system, a main system has been generated for certain important international passes, as has a technical cooperation system between the national authorities and the various provinces.

Over the past 30 years, this has helped improve the way these phenomena are addressed, and has reduced closure times on the main roadways.

Work still to be done includes systematization of experiences, collection of specific data from each of the affected regions and cities, and the expansion of network operating protocols.

Future challenges will include the need for:

- Incorporating new technologies for winter road management, with priority attributed by service level.
- Reducing road-closure days due to dysfunctional winter maintenance, an objective we share with our neighbouring country.
- Infrastructure roadworks that are compatible with winter maintenance
- Implementing adequate logistics to optimize resources and make winter road maintenance tasks efficient.
- Continued research into new anti-freeze products that are environmentally-friendly, more effective, etc.
- ITS technology (variable signalling signage, cameras, weather station technology and sensors for pavement, temperature and salt residue on roadways)
- Ongoing coordination between border crossings and districts for the purpose of maintaining reasonable passability between countries
- Training and exchange of knowledge and experience
- Improves communications.

AUSTRIA

1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

FIGURE 1 – REPUBLIC OF AUSTRIA

Austria is situated in the southern part of middle Europe. The neighboring countries are in the north, Germany and the Czech Republic, in the east, Slovakia and Hungary, in the south, Slovenia and Italy and in the west, Switzerland and Liechtenstein.

The size of the country is 83,879 km^2, with a population of 8.468.70 million. The topography is dominated by the Eastern Alps and the Danube area.

Vienna, the capital of the Republic of Austria, is on the eastern part of the country. The city comprises 414 415 km^2, with a population of 1.731.81 million.

Austria is a highly developed industrialized country with a significant tertiary sector. Chemical and electrical industries, agriculture and tourism are the main parts of the local economy.

The land has an extensive road and railway system. The Vienna International Airport is a central junction for flights between the western and eastern part of Europe.

The country is a democratic federal state, which consists of nine regions including:

Wien (Vienna) (1.731.84 million people),
Niederösterreich (1.621.65 million people),
Burgenland (0.29 million people),
Oberösterreich (1.421.45 million people),
Salzburg (0.530.55 million people),
Steiermark (1.211.23 million people),
Kärnten (0.56 million people),
Tirol (0.710.74 million people) and
Vorarlberg (0.370.39 million people).

Motorways and federal highways are privately owned by the enterprise ASFINAG. There is a duty for all vehicles. Car and motorcycle holders have to buy a vignette for using the motorways.

Buses and trucks must be equipped with a so-called „go-box".

The road network system is administered (planning, structural preservation and winter maintenance) by the regions.

1.2. Road network and Traffic

Area	83,879 km2	
Population	8.468.70 million	
Length of roads	Motorway Regional main roads secondary & country roads municipal roads	2,1852,208 km 9,95910,345 km 23,68023,681 km 78,766102,463 km
Latitude (capital)	48° 13′ 11″ N	
Longitude (capital)	16° 22′ 12″ O	

Table 1

The network of the public roads comprises approximately 114,590138,696 km. There are 6.27.29 million vehicles with Austrian traffic certification. 4.54.75 million passenger cars driving an average 12,410 km per year.

2. CLIMATE

2.1. OVERVIEW OF CLIMATIC AREAS

Austria is a mostly Alpine country, situated in a transition zone between continental and maritime climate. The winter climate is marked by the changing influence between moist, moderate air masses steered towards Austria from the Atlantic Ocean, and cold dry air, related to strong areas of high pressure over Eastern Europe.

Concerning the occurrence of heavy snowfalls Austria can be divided into distinct zones:

- Northern Austria frequently receives great amounts of fresh snow, when moist air is steered with a northwesterly flow towards the Alps. Hitting with the northern rim of this mountain range, the air rises, thus cools and is unable to keep its moisture, which falls as snow to the ground;
- Heavy snowstorms hit Southern Austria in connection with Mediterranean lows centered over Northern Italy;
- In the lowlands of the Eastern and Northern Austria, heavy snowfall is unusually rare and occurs in connection with cold air from Northern Europe or, like in Southern Austria, related to lows over the Mediterranean Sea, if temperatures are low enough for snowfall;
- Freezing rain may affect Austrian roads a couple of times each winter. It sometimes occurs when warm fronts approach the country from Western Europe and the falling rain or drizzle freezes when hitting a thin layer of cold air close to the surface.

Fog or freezing fog may also be a problem for the traffic. This occurs in connection with marked temperature inversions, when cold air from Eastern Europe is topped at altitudes of 600 to 1,200 m by a much warmer layer of air.

Drifting snow can cause catastrophic conditions on the roads in the flat and thus wind-prone parts of Austria if temperatures are sufficiently low.

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

The traffic regulations are the legal foundation for all winter maintenance activities. Road operators are responsible to maintain a proper road condition which includes winter maintenance. The winter maintenance procedures on roads are divided in rural roads (table 2) and urban roads (table 3) with 4 (rural) or 7 (urban) different categories.

In case of snowfall or slipperiness sidewalks must be maintained between 6:00 (6:00 am) and 22:00 (10:00 pm). Responsible are the owners of the neighboring properties.

3.2. Organization and operation of winter maintenance

Motorways and federal highways are administrated and operated by the ASFINAG (Autobahn und Straßen Finanzierungs AG). Roads of the countries or municipalities are administrated by the regions (Lands of the Federal Republic), the cities or municipalities. There is no winter maintenance head office in Austria which is giving instructions to the road authorities.

3.2.1 SURVEYOR OF HIGHWAYS

Road Master

Austria has around 240 service centers led by so-called surveyor of highwaysroad masters with huge responsibilities. They are charged with the organization of a service station during the summer and wintertime. Some Part of their jobs are is planning, executing and monitoring of activities concerning road administration. They also have to check the weather reports and make decisions in case of prognosis, which have an effect concerning the road condition.

	Category A	Category B	Category C	Category D
Weather situation, road condition	Highways, Motorways and their junctions	Regional Roads with a daily traffic volume of more than 5,000	Regional Roads with a daily traffic volume between 1,000 and 5,000	Regional Roads with a daily traffic volume less than 1,000
2. Light Snowfall, snow and ice, light snow drifts	Trafficability of all lanes, junctions and access roads to service stations. Treatment with de-icing agents - Complete clearance. Snowy road might occur	Trafficability; Treatment with de-icing agents favoured. Snow depth up to 10 cm possible. Detractions between 22-6 cannot be excluded.	Trafficability; Treatment with de-icing agents or grit; Snow depth up to 10cm possible. Heavy detractions between 20-7 and on Weekend can't be excluded.	Trafficability; Treatment with grit or de-icing agents. Heavy detractions cannot be excluded.
3. Heavy Snowfall, snow drifts	Trafficability of at least one lane per direction, junctions and access roads to service stations between 0-24. Treatment with deicing agents - Complete clearance favoured. Snowy road might occur. Trafficability of parking lots and hard shoulder not ensured. Trafficability if necessary with snow chains.	Trafficability of at least one lane per direction. Treatment with de-icing agents favoured. Heavy detractions due do snow depths of more than 10 cm possible; Trafficability if necessary with snow chains.	Trafficability of at least one lane per direction. Treatment with de-icing agents or grit. Heavy detractions due do snow depths of more than 10 cm possible; Trafficability if necessary with snow chains.	Trafficability of at least one lane if necessary with snow chains. Treatment with grit or de-icing agents. Snow clearance from snow depths of 10 cm (8 to 20 clock).
		In case of gritting - only after completion of snow removal		
4. Heavy snow drifts, avalances, extreme ice (e.g. freezing rain)	Trafficability cannot be ensured. Temporary road closures might appear. Information of road users carried by media and police.			
Winter Maintenance service time	00 - 24 Treatment intervals as required	4 - 22 Treatment intervals as required	5 - 20 Treatment intervals as required	8 - 20 Treatment intervals as required
Time of circulation	max. 3 hours	max. 5 hours	max. 5 hours	_
Annotation	Time of circulation = Time between 2 Treatments, Trafficability = Use by vehicles with winter gear possible, Heavy Snowfall = More than 10 cm in 3 hours			

Table 2: Winter maintenance categories on rural roads

	P1	P2	P3
	Inner-city main roads, access roads, roads with bus lines / trams, roads to access public hospitals and fire stations	Roads with minor traffic importance, feeder roads in residential and commercial areas, mountain roads	Roads with minor traffic importance, rural character
Sort of treatment	Ploughing and spreading	Ploughing and spreading	Ploughing and spreading
Service time	4-22	5-22	6-22
Max. snow depth	10 cm	10 cm, more at night	10 cm, more at night
Treatment interval	max. 5 hours	max. 12 hours	max. 12 hours
Treatment with	De-icer favoured	De-icer favoured, if applicable abrasives	Abrasives, de-icer if necessary
Surface condition after treatment	Wet or dry road, slight detractions possible	Wet or dry road, sporadically ice on road possible	Snowy roads and detractions possible

Table 3: Winter maintenance categories on urban areas (Weather condition: Light Snowfalls)

	P4	P5	P6	P7
	Separated cycling lanes connecting neighbourhoods or with significance for commuter traffic	Separated cycling lane as a connection with a local access function or leisure travel	Designated sidewalks, pedestrian areas, school routes, paths in the area of hospitals, stops of public transport within the remit of the local authorityz	Parking spaces, parking areas, parkways, other trafficked areas
Sort of treatment	Ploughing and spreading	Ploughing and spreading	Ploughing and spreading	Ploughing after other Treatments
Service time	6-19	6-19	6-22	not specified
Max. snow depth	10 cm, more at night	Detractions possible	Detractions possible	Detractions possible
Treatment interval	max. 12 hours	as required	According §93 StVO or §1319a ABGB	none
Treatment with	De-icer favoured, if applicable abrasives	De-icing or abrasive	De-icing or abrasive	De-icing or abrasive
Surface condition after treatment	Dry road, sporadically ice or grit on road possible	Trafficability sporadically ice or grit on road possible	Dry road, sporadically ice or bumps on road possible	According to the possibilities. Restrictions due to snow deposition possible

Table 3: Winter maintenance categories on urban areas (Weather condition: Light Snowfalls)

3.2.3 Spreading techniques

There is a statutory duty that winter maintenance must be executed on all public roads in Austria. The kind of spreading material depends on the category of the road (see table 2). On category A roads, the spreading of salt is obligatory, the use of grit is not allowed. On categories B and C, there is a mix of salt spreading routes, routes with a mixture of salt/grit (for example ratio 1:10) or routes where the road administration is using grit only.

The application of prewetted salt (F 30 technology) is common practice (fig. 2). If trucks are not equipped with the necessary devices, it is possible to load a mixture dry salt (stone or vacuum salt) and grit.

With new developments in spreading technique and research projects higher brine rates (50% to 70%) are

FIGURE 3 – SNOW CUTTER BLOWER IN THE AREA OF LILIENFELD (LOWER AUSTRIA)

used in several regions starting 2015. Also combined spreaders capable of spreading prewetted salt or only brine are in use.

Figure 2 – Trucks with plow and F 30 equipment for urban or highway use – Combined spreader for prewetted salt and brine using spreading nozzles

Winter services in alpine regions often require the employment of snow cutter blowers. Due to the avalanche danger in many areas of the Alps, temporary roadblocks are made. The Prealps area 60 km west of Vienna (fig. 3) is concerned with violent snowfall very often. The use of snow cutter blowers is usual in winter service activities in the alpine region.

Some high-altitude roads remain closed completely during the winter period. Snow clearing activities start in April. For the Großglockner Hochalpenstraße (fig. 4) 25 working days are necessary to remove 600,000 m^3 to 800,000 m^3 of snow. The snow walls have a height of up to 21 m.

FIGURE 4 – SNOW REMOVAL AT THE GROSSGLOCKNER HOCHALPENSTRASSE

3.2.4 Environmental consequences of de-icing agents and grit

The use of de-icing agents can have negative repercussions on the environment. On many roads in Austria the use of chlorides are is prohibited due to environmental reasons. Some kinds of trees (for example, chestnut or plane tree) are very sensitive to salt or calcium chloride. To reduce the harmful effects to a minimum, it is necessary to use de-icing agents, which are less harmful. In some areas of Vienna potassium carbonate is used instead of sodium chloride. This is necessary on roads where the spreading of grit is not sufficient to keep the roads safe.

FIGURE 5 – TRUCK "FIRESTORM" WITH BRINE SPRAYING DEVICE

There is also a dust when you are using grit during the winter maintenance. Normally the surface temperature has to reach +3 C or more to use sweeping machines. These machines spread water to prevent a kick up of a lot of dust before the sweep in the grit. The city of Vienna is also using sweeping machines (fig. 5) which also use sodium chloride brine instead of water. Sweeping of the road surface can be accomplished with temperatures below the freezing point during a dry weather period.

3.2.5 Road weather information system

The 9 Lands of the Federal Republicroad authorities have special contracts with the weather service institutes. There are several weather forecasts for the whole country, but with consideration of the climate within a small area, a large number of special weather reports are required. Some of the most important weather institutes are:

- The Central Institute of Meteorology;
- Austro Control (flight weather);
- The military weather service;
- Meteomedia and so on.UBIMET

The following weather values are common for road winter service:

- Air temperature [°C];
- Surface temperature [°C];
- Wind direction and strength (average and peak values);
- Weather condition and tendency;
- Weather effectiveness (e.g., weak, moderate, strong);
- Precipitation type (e.g., drizzle, rain, snow rain, snow, ice);
- Type of precipitation (e.g., shower, freezing rain, from time to time)
- Intensity (e.g., shower, freezing rain, from time to time, easy, moderate, strong);
- Snowfall limit [m];
- Quantity of fresh snow [cm];
- Remarks of the meteorologist.

The responsible persons have to collect this information. With the help of these reports they can make their decisions.

The Austrian roads have over 370 500 ice forecasting systems installed mostly on highways. The measured values are transmitted by leased lines to the road administration. In exceptional cases selecting modems are used. Generally, the stations are set up at the coldest points of the roads and bridges. The determination of the location of new stations takes place through thermal mapping and the experience of the road master or drivers of snowplows.

Some road administrations have a connection to the weather radar and EUMETSAT system. It is very important additional information allowing the road master to make decisions concerning the start, duration and end of a winter maintenance action.

3.2.6 Traffic safety and road information for drivers

The individual radio and television stations inform about the forecasted and current weather and the road conditions. Weather information is also available on the internet and for smartphones. Weather cameras are installed on certain points of the whole country. The weather situation can be observed both in the tourist region as well as in the urban areas. Since 2008 winter tires are compulsory on snowy or icy roads between November 1st and April 15th. Even though this regulation was made most handicaps are caused by insufficiently equipped vehicles.

Information concerning winter road conditions should be given as early as possible. Some road signs indicate a speed limit for the danger of smooth roadways. The police can prescribe the use of tire chains on certain roads.

3.2.7 Snow stockpiles for urban areas

Winter maintenance in urban areas has some special emphasis, which does not play a role on highways. Due to a lack of road space large quantities of snow must be removed rapidly. For this reason there are snow stockpiles (fig. 6) in larger cities. The snow can be poured into flowing water. That is problematic due to environmental protection reasons, because a lot of grit and

FIGURE 6 – SNOW STOCKPILE

other materials are mixed in the snow. Or stored at

The storage of snow takes place on so-called snow dumping sites. At these places the snow thaws slowly off and the residual substances can be removed after the winter.

4. On-going Research and Studies to Improve Winter Management

The Austrian Research Council Road and Traffic is responsible for all activities concerning research of all kinds of road construction and maintenance.

Among other things there is a working group, which concerns itself with winter maintenance. Guidelines and instructions are compiled regarding the efficiency in winter maintenance.

The comparison of typical winter maintenance situations with practical application rates shows a high potential of savings by preventing unnecessary salting. This leads to the question of optimized application rates and winter maintenance strategies for all typical situations that can still be applied in winter maintenance practice. To answer these questions the federal states of Austria, the Austrian highway operating company (ASFINAG) and the federal ministry of Transport (BMVIT) funded a research project at the Vienna University of Technology. Based on extensive field and lab testing from 2010 to 2012 at the Institute of Transportation the complex mechanical and physical impact of all main factors and their influence on winter maintenance could be discussion with selected personnel completed the verification and implementation of the findings in a comprehensive winter maintenance model. Further results include a compact practical winter maintenance guide and training courses for winter maintenance personnel.

In addition to treatment principles, winter maintenance strategies, application rates, and driving recommendations for typical winter scenarios have been developed. These scenarios consist of clearly distinguishable road conditions and weather development scenarios according to their importance for winter maintenance and road users. These scenarios are given in Table 4 with pictures of typical road conditions and an overview of winter maintenance strategies. The winter maintenance recommendations do not replace local expertise and responsibility of the winter maintenance staff and adaptation of application rates for special requirements (e.g. on bridges, drain asphalt, etc.). However, they encourage a harmonized appraisal of the situation in order to achieve better winter maintenance results.

Based upon the results of this project a follow up projects have been conducted dealing with Current research projects considering new salt application technologies, new de-icing agentes and the evaluation of sensor based winter maintenance possibilities decision making. will be finished in summer 2013. As a result, many road authorities use higher brine ratios for prewetted salting. Spreading machines and brine mixing plants are about to become adapted to the new requirements.

A research project funded again by the federal states of Austria, the Austrian highway operating company (ASFINAG) and the federal ministry of Transport (BMVIT) started 2016 and will be finished 2018. The scope of the project is the determination of the physical behavior of salt, brine and prewetted salt on the road. Also the effectiveness of anti- cakcking agents and the behavior of residual salt on the road are considered. In addition different type of snow ploughs are evaluated.

5. REFERENCES

Magistrat der Stadt Wien, MA 48: Abfallwirtschaft, Straßenreinigung und Fuhrpark

Amt der Niederösterreichischen Landesregierung

Asfinag Service Gesellschaft, www.asfinag.at

Anforderungsniveau für den Winterdienst

Österreichische Forschungsgesellschaft Straße - Schiene - VerkehrDer Forschungsgenmeinschaft Straße und Verkehr

http://www.grossglockner.at/de/grossglockner/

Optimierung der Feuchtsalzstreuung

http://www.bmvit.gv.at/service/publikationen/verkehr/strasse/feuchtsalzstreuung.html

Eignungskriterien auftauende Streumittel

https://www.bmvit.gv.at/verkehr/strasse/sicherheit/fonds/vsf/downloads/45_eignungskriterien_streumittel-v2.pdf

PICTURE DOCUMENTARY	ROAD CONDITION	TREATMENT RECOMMENDATION
	Dry road: No sleekness expected Surfact temperature: -30°C to +60°C High skid resistance, μ = 0,6 – 1,0 Hoarfrost possible or expected (usually at 2 - 4 am)	Minimal salting only at hoarfrost: No treatment required Preventive treatment 5 – 10* g/m² with beginning hoarfrost
	Moist or wet road: Road surface temperature > 0° C Moderate skid resistance, μ = 0,4 – 0,7 Road surface temperature ≤ 0°C Moist road Moderate skid resistance, μ = 0,2 – 0,6 Road surface temperature ≤ 0°C Wet road Very low skid resistance, μ = 0,1 – 0,6	Salting at temperatures below 0°C: No treatment required (Watch temperature!) Preventive treatment with 5 – 10* g/m² Before beginning freezing Treatment with 20 to 40* g/m² before freezing critical Warning messages if black ice forms!
	Snow next to wheel tracks: No snowfall Wheel tracks free of snow Moderate skid resistance, μ = 0,3 – 0,5 Snowfall less than 0,5 cm/interval Low skid resistance, μ = 0,2 – 0,4 Snowfall more than 0,5 cm/interval Snow in wheel tracks Low skid resistance, μ = 0,2 – 0,4	Ploughing and salting: Ploughing and salting with 10 – 20* g/m², to remove remaining snow Ploughing and salting with 10 – 20* g/m² Ploughing and salting 10 g/m² (release coating!) until end of snowfalls, then ploughing and salting with 10 – 20* g/m²
	Snow in wheel tracks: No snowfall Road covered with snow Low skid resistance, μ = 0,2 – 0,3 Snowfall less than 0,5 cm/interval Low skid resistance, μ = 0,2 – 0,3 Snowfall more than 0,5 cm/interval Very low skid resistance, μ = 0,1 – 0,3	Ploughing and salting: Ploughing and salting with 20 – 30* g/m², to remove remaining snow Ploughing and salting with 10 – 20* g/m² Ploughing and salting 10 g/m² (release coating!) until end of snowfalls, then ploughing and salting with 20 – 30* g/m²
	Very low skid resistance No precipitation Road surface temperature ≤ 0°C. Very low skid resistance, μ = 0,05 – 0,2 Black ice and further precipitation (Snow or rain) Very low skid resistance, μ = 0,05 – 0,2	Salting as required: Preventive treatment if possible, Maximum treatment at critical/icy Spots, Further treatments as necessary Maximum treatment until ice is cleared Closure of road sections as necessary. Opening after closure only if skid resistance is sufficient

TABLE 4: WINTER MAINTENANCE RECOMMENDATIONS

1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

BELGIAN ROAD NETWORK (MAIN ROADS)

Belgium is a country small in size (30,528 km^2) but densely populated (10.67 million), situated at the heart of Europe. The country occupies a privileged position between the Netherlands, France, Germany and Great Britain, and borders on the North Sea, the busiest sea route on the globe. Brussels, the country's capital, is also the capital of the European Union and an international financial centre. The country's flourishing economy is largely built on the export trade (2/3 of the country's production is exported). Belgium's financial health depends to a large extent on its transportation infrastructure. The motorway and railway network is accordingly one of the densest in the world.

The country is a federal state with 3 regions: the Flemish region in the north (6.16 million people), the Brussels-Capital region in the centre (1.05 million), and the Walloon region in the south (3.46 million). These three regions are autonomous in several areas, including the construction, management and maintenance of the motorways and expressways on their territories. Flanders and the Brussels-Capital region are relatively flat regions (0 to 100 m), whereas the Walloon region contains the Ardennes, a group of plateaus 400 to 690 m in altitude and dotted with numerous valleys.

1.2. ROAD NETWORK AND TRAFFIC

The road network comprises 1,763 km of motorways, 12,613 km of regional (national) roads (both managed by the regional authorities) and 139,219 km of communal and provincial roads.

Area	30,528 km^2	
Population	10.67 million	
Length of road	Motorways	1,763 km
	Regional roads	12,613 km
	Provincial roads	1,349 km
	Local roads	137,870 km
Latitude (capital)		50°50'N

2008 STATISTICS ON THE COUNTRY AND ROADS (HTTP://WWW.BELGIUM.BE; HTTP://STATBEL.FGOV.BE)

Of the 6.48 million vehicles in Belgium, 5.13 million are passenger cars, each travelling an average distance of 15,636 km per year (2007). Traffic is also significant at night, particularly commercial traffic. Road transportation accounts for 73% of the total freight transportation. The average daily traffic (2007; 6 a.m.-10 p.m.) on Belgian motorways is around 51,000 vehicles (with maximums reaching close to 150,000 on certain segments near major cities) and about 10,000 vehicles on regional roads.

Traffic: 98.79 billion veh-km	
On motorways:	35.85 billion veh-km
On regional roads:	40.70 billion veh-km
On communal roads:	22.24 billion veh-km
By passenger cars:	77.02 billion veh-km
By trucks (and commercial vehicles) for freight transportation:	19.71 billion veh-km

2007 TRAFFIC STATISTICS (HTTP://STATBEL.FGOV.BE)

The economic importance of roads can therefore not be denied, even in winter. As a result, one of the tasks of the road authorities is to keep the road network serviceable at all times, among other things by setting up a special department for winter maintenance.

2. CLIMATE

2.1. OVERVIEW OF CLIMATIC AREAS

Due to the geographic location of the country, the climate is largely influenced by the proximity of the sea. Moving towards the interior, behind a coastal plain a few kilometers wide, the terrain rises gradually towards the south and southeast and is characterized by numerous valleys. This diversity leads to significantly different local microclimates that must be considered in the management of winter road maintenance.

2.2. STATISTICS ON TEMPERATURE, FROST DAYS AND PRECIPITATIONS

Belgium has a temperate climate with relatively mild and rainy winters. In winter, the weather conditions can be very irregular at around 0 °C. Frequent and abundant precipitations in winter, mostly in the form of rain or winter showers, make the roads wet or damp. The number of days of snow varies considerably depending on where you are within the territory: from around 12 days/year on the coast to 60 days/year on the Ardennes plateaus [3]. The number of frost days in Brussels remains limited, at 52 days per year. It is the number of freeze-thaw cycles that most characterizes the winters in Belgium. In general, the closer you get to the Ardennes plateaus, the more the average temperature drops and the number of frost days increases, up to an average of 115 days per year. Locally the differences in climate conditions between road sections are significant enough to create different types of skidding conditions.

2.3. WINTER INDICES USED IN THE COUNTRY

No winter indices as such are used in Belgium. "Consumption" indices taking the severity of winter into account are used.

Balanced scorecard: The Flemish road authority calls on a number of resources (both human and financial) to achieve its strategic and operational objectives. One of these strategic objectives is to minimize the impact on the environment. It is accordingly important to analyze whether any of the measures (excessive interventions, dosing that is too high) taken for winter maintenance were greater than necessary. The ultimate goal is to use as little salt as possible and still achieve the operational objective (avoiding slippery roads). Consequently, an M (= Z/R) index was developed, the latter representing the relation between the quantity of salt spread (Z) and a reference value R defined by the following formula:

$$R = \sum_{i=1}^{9} Oi \times (7g/m^2 \times X1i + 33g/m^2 \times X2i) / 106$$

where:

O: is the area of road treated in each of the region's 9 climatic areas.

X1: is the number of nights during which the road surface temperature fell below 0 and where the dew point was greater than the road surface temperature.

X2: is the number of nights during which winter showers or snowfalls on an icy surface were recorded.

The Walloon road administration also develops quality standards and performance indicators associated with the harshness of winter (see § 4.2).

3. WINTER ROAD MANAGEMENT (ON REGIONAL ROADS AND MOTORWAYS)

3.1. STANDARDS AND REGULATIONS

Legal obligation to perform winter maintenance

The winter maintenance performed by the three regional administrations is a service provided to road users and to the country's economy. Winter service is

performed between mid-October and mid-April.

Classification of roads - Levels of service - Route optimization

The level of service allocated to roads aims, insofar as the circumstances allow it, to ensure maintenance or to re-establish normal traffic conditions in all unexceptional winter situations, taking into account the road classification and the volume of traffic. For each level of service required, winter maintenance operations must be completed within 4 hours of the decision to act.

Theoretically, the serviceability of every road is maintained. In the event of extreme winter conditions, and when available resources become insufficient, priority is given to certain roads (motorways, major national roads, roads used by public transportation). The administration must take the actions (spreading, snow removal, signage, etc.) necessary to ensure that ice or snow does not unduly surprise the users.

Quality standards, performance indicators

Winter maintenance contracts are currently still aimed at securing means rather than achieving actual results or service levels.

Manpower regulations

The organization of local winter maintenance is set out in detail in an organizational plan (internal regulations) specific to each district. This document sets out how each task associated with winter maintenance is organized.

Work is scheduled according to Belgian legislation on work time adopted on 2000-12-14.[3] This legislation stipulates that work time may not exceed an average of 38 hours per week over a reference period of 4 months (without exception).

Regulations regarding the types and characteristics of materials and equipment

Most of the salt used on Belgian roads is sodium chloride (NaCl), either as rock salt, evaporated salt or brine. Supply contracts are established before the winter period (in Walloon: three-year contracts broken down in three annual phases, with a revision in the 2nd and 3rd years of the unit prices initially set); these contracts specify the characteristics that the salt must have (purity, anti-caking agents, grain size) as well as the anticipated quantities and packaging.

Suppliers are required to provide evidence of the existence of appropriate stock levels in Belgium. In particular, the Walloon region requires that salt stocks be transported via inland waterways and ports (to encourage intermodality). Supply contracts allow for three forms of NaCl (brine, evaporated salt and rock salt with a wide range of grain sizes) annually.

Generally speaking, detachable spreaders designed for medium and large road systems (capacity of around 5 m^3) are used; they are wheel driven, driven by an auxiliary engine, by the truck's hydraulics or connected to one of the truck's axles.

Each regional administration has established its own technical requirements regarding spreaders (attachment, signage, drive system and feed system), but in general the spreaders must always be equipped for the spreading of wet salt (brine tanks, feed lines, etc.) as well as with a system to accurately adjust the spread width and rate. The tender specifications refer amongst other things to the CROW 131 publication.[2]

Most of the spreaders operated in Flanders have been equipped with a system that automatically collects and analyses spreading data since 1996.

The trucks used for winter maintenance by the Ministry of the Brussels-Capital Region are equipped with a real-time GPS tracking system. Such a system is also being deployed in Walloon (see § 4.1).

Flemish region		
	Motorways	Regional roads
Districts	93 km/district	275 km/districts
Spreaders (near 5 m^3) & snowplows	8.1 km/spreader	24 km/spreader
Walloon region		
Districts	87 km/district	212 km/district
Spreaders (near 5 m^3) & snowplows	7.5 km/spreader	26.5 km/spreader
Brussels-Capital region		
Districts	11 km/district	320 km/district
Spreaders (near 5 m^3) & snowplows	3.7 km/spreader	20 km/spreader
Belgium (average)		
Districts	86 km/district	229 km/district
Spreaders (near 5 m^3) & snowplows	7.8 km/spreader	23.9 km/spreader

km of roads include both directions, on-ramps, off-ramps and interchanges

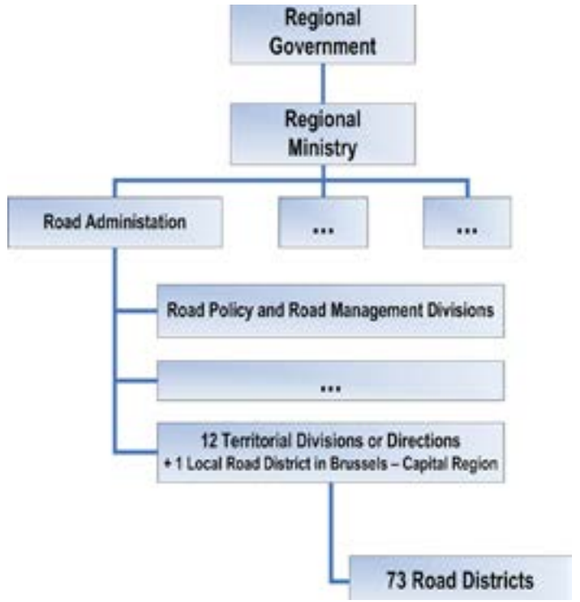
Road management: districts and equipment—in the event of maximum deployment (this is an average situation and is the result of dividing the number of km by the total number of districts, spreaders and snowplows)

Regional road administrations call on a number of private companies (truck and driver rental, as well as spreader rental in Walloon), whose equipment is tested and eventually calibrated before the start of the winter period. In general, the salting routes, the number of spreaders and their capacity is determined in order to complete each salting route within 4 hours of the decision to respond (response time after the call to start treatment is 1 hour; the treatment time itself is around 2-2.5 hours), considering an average salting rate between 15 and 30 g/m^2.

3.2. ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The organization of winter maintenance along Belgian roads is the responsibility of:

- The three regional authorities for the 14,376 km of regional roads through various central branches and 74 local districts; all winter maintenance operations are carried out or ordered by these local centers.



Decentralization of the road winter management

- The local authorities (589 communes and 10 provinces) when communal or provincial roads are concerned (these roads were not reviewed in this document).

District tasks

Winter maintenance by the districts comprises the following three main tasks:

A steering role for the district manager, who is charged with controlling the smooth conduct of winter maintenance and provides the necessary guidance to make sure that instructions are well understood and applied,

A coordination role for the "winter maintenance coordinator" who ensures the day-to-day running of operations. After taking cognizance of the road weather conditions (observed and forecast) and the results of road inspections, he makes the necessary decisions for interventions, calls up the necessary staff members and private contractors, and determines the type of treatment to be applied and the quantity of salt to be used. Finally, he is responsible for seeing to the encoding or recording of data associated with the delivery of services and management of ice melters (see also § 4.2);

An implementation role for private contractors (mainly); the logistical support of contractors consists in supplying trucks with drivers as well as, sometimes, spreaders for salt solutions (only in Walloon, since 2000) and snow ploughs.

These tasks are set out in various internal documents and updated every year (general organization plans, territorial plans, and district level plans).

Public/private partnership for the implementation of winter maintenance

The implementation of winter maintenance on most routes is entrusted to private contractors.

	Level of privatization	% of operations (most recent winters)
Flemish region	Driver & truck	100%
Brussels-Capital region	Driver & truck	near 97%
Walloon (240 private contracts)	Driver, truck & spreader	86% (2008-2009 winter)

Interventions carried out by private contractors

Contracts with private contractors are signed before the winter maintenance season; they are based on

a standard contract. Depending on the competent authority concerned, various types of contracts describing the winter maintenance operations to be carried out on a well-defined itinerary are used in Belgium:

Twice-renewable one-year contracts in the Brussels-Capital region;

Contracts for three winter periods with a formula for the annual revision of unit prices in Walloon (these include rental of the spreader belonging to the private company);

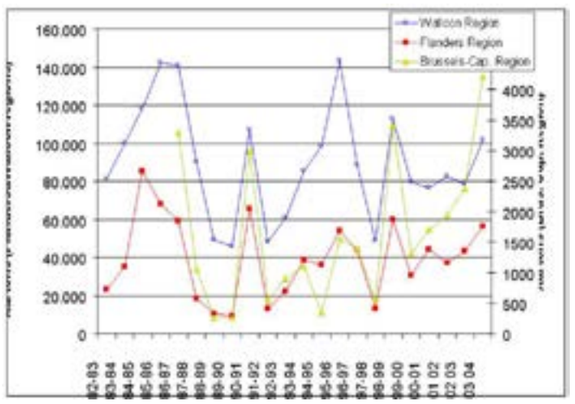
Three-year contracts (two years for bicycle paths) in Flanders. The spreaders and salt are supplied by the administration.

Salt contracts and directives

Every year, a central branch of each road administration awards contracts to various salt suppliers following an open tendering process, so that the winter stocks can be replenished. These contracts for salt supplies are concluded at the central level in order to derive maximum price benefit from large volumes. The central branch also monitors the implementation of the contracts. Furthermore, it draws up directives for salting under various road conditions (at low temperatures, on ice, on porous asphalt, etc.) and works with industry to further develop winter maintenance material, etc.

Cooperation with other road management organizations

Agreements are in place between the regional administrations as well as with local authorities to optimize salting routes along the network as well as to organize interventions on a few specific routes.



Annual consumption of salt on Belgian regional roads

In addition, the Walloon region makes the information obtained from its road weather system available to Walloon communes to assist them in their decision -making. A replication of the portion of the application relating to meteorological data was developed in 2007 to this end.

Financing winter maintenance

Annual salt consumption is linked to the severity of winter. In the 1982-2009 period, the total annual consumption of road salt (NaCl and CaCl2) along the roads that make up the regional networks was as follows:

To date, the spreading of CaCl2 along the regional networks represents less than 1% of the total salt consumption.

	Walloon region	Flemish region	Brussels-Cap region
Average for the 2003 to 2008 winters – in tonnes	80,931	44,586	3,154
km²	7,192	7,650	
g/m²/year	11.25	5.83	

Salt use in Belgium: 2003-2008 period

The average annual cost of winter maintenance in Belgium (most recent winters) is about 0.25 Euro/m² (ranging from 0.15 to 0.75 Euro/m² depending on the location of the road).

The total winter maintenance costs (average of most recent winters) can be divided as follows:

	Purchase of de-icing salts	Equipment and personnel	Involvement of private sector
Flemish region	26%	29%	45%
Walloon region	17%	26%	58%**

Breakdown of total winter maintenance costs: 2003 to 2008 period

Operational management of winter maintenance—snow and ice control measures

Interventions are organized as salting routes; the spreader is loaded so as to complete an entire circuit. Circuits are repeated as required. The spreaders are loaded directly from a vertical silo or from a horizontal silo using a loader.

EXAMPLE OF SALT SILOS USED IN BELGIUM

There are three types of spreading, depending on the circumstances:

- Localized spreading: to avoid local frost or black ice, or to de-ice locally. The decision to respond and the rate of spreading depend on weather conditions (meteorological analysis of specific critical points in the affected district); the recommended rate varies from 7 to 10 g/m² (anti-icing) and from 20 to 30 g/m² (de-icing);
- Generalized anti-icing (pre-curative) spreading: to avoid general frost or black ice over the entire network, or to prevent precipitations from sticking to the road surface. The recommended rate (pre-wetted salt is very often used) falls between 7 and 15 g/m², depending on road weather conditions and forecasts. These interventions are carried out following a predefined morning and/or evening schedule;
- The generalized curative spreading of ice melters is carried out during or after the precipitations or winter event, and the spreading rates usually vary between 20 and 25 g/m² with a localized maximum of up to 40 g/m².

Coordinators are instructed to focus on spreading preventively (pre-curative) as often as possible. Pre-salting is done with pre-wetted salt (7 to 15 g/m² - i.e., 80% dry salt pre-wetted with 20% of concentrated brine with 22% of NaCl). Spread width and symmetry can be adjusted on all spreaders from the cab, according to road width and number of lanes.

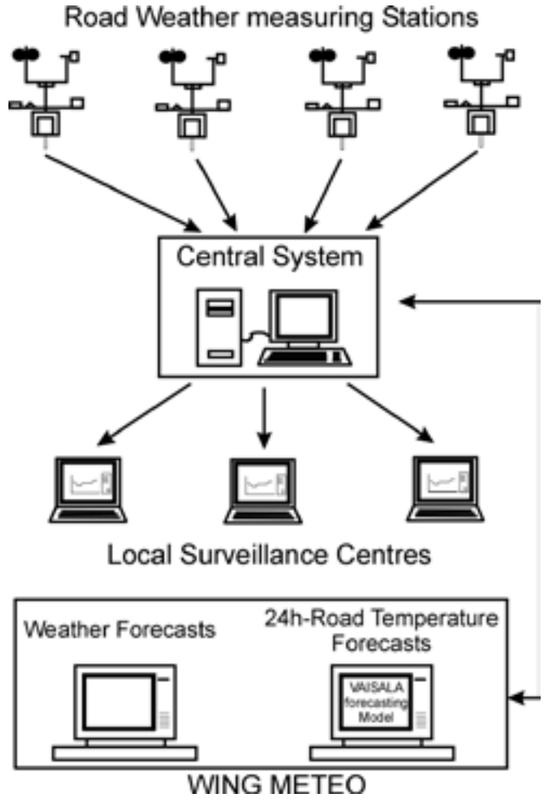
The Flemish road administration fosters the use of evaporated salt for anti-icing with pre-wetted salt and coarse salt for de-icing. There is no spreading of abrasives.

Contracts also include the delivery of generalized or localized snow removal services, combined with a spreading and executed serially (simultaneous snow removal in multiple lanes) as needed.

Wet salt technique

The Flemish road administration has adopted a policy for the complete renovation of its fleet of salt spreaders over a period of twenty years—starting in 1990—by buying only wet salt spreaders.

The same progressive spreader renewal is going on in the Brussels-Capital region (in winter 2009-2010, 90% of spreaders will be equipped for spreading wet salt), and since 2000 the Walloon road administration started new contracts with private contractors for win-



SCHEMATIC DIAGRAM OF A ROAD WEATHER INFORMATION SYSTEM

ter maintenance operations that also include the rental of wet salt spreaders.

Road weather information system and method

Observations from road network inspections, those made by Road Weather measuring Stations (RWS), the weather forecasts supplied by the Belgian Air Force's weather section (WING) and those regarding road temperature, as well as knowledge of the features of the local road network are the main elements allowing the coordinator to make appropriate decisions in relation to winter maintenance.

The Road Weather Information Systems as a decision support tool

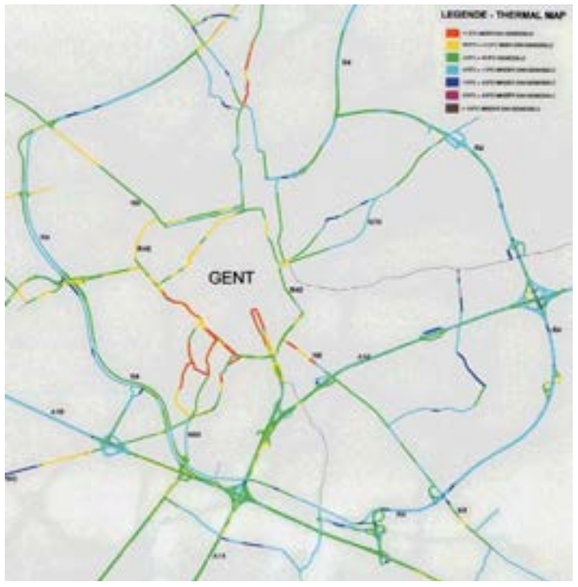
Principle: The RWIS allows for the automatic collection of data related to road surface conditions, as well as local meteorological data, and aims to improve road safety by anticipating the weather conditions likely to result in slippery roads.

Two road weather systems are in operation in Belgium (Flemish and Walloon regions); on the whole, they are composed of the following:

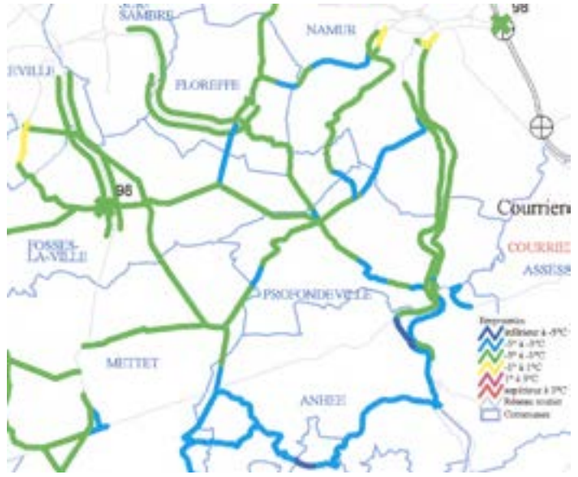
1. 99 Road Weather measuring Stations (RWS) located along the Flemish and Walloon road networks. Each region was divided into relatively homogenous climatic areas and the RWSs were installed in strategic locations for winter maintenance. There are two types of RWSs, which differ in terms of equipment: Primary stations (34): Essentially installed along roads with intense traffic, they are equipped, on the one hand, with atmospheric sensors measuring temperature and air humidity, wind speed and direction, the type, intensity and total precipitate volume, global and atmospheric radiation, and, on the other hand, with road sensors that measure changes in the road temperature on the surface as well as at depths of 5, 10 and 20 cm; Secondary stations (65): Similar but smaller, they do not measure wind characteristics or road temperatures at depths of 10 and 20 cm, nor do they collect any data regarding radiation.
2. The central system downloads and archives data from each RWS every 6 or 10 minutes,
3. Observations are also transmitted to the WING (meteorological office), which provides weather and change forecasts regarding the road surface temperature. The former are provided at midday and cover a 24-hour period; these are adjusted if a deviation (> 1°C) from subsequent observations of the road surface temperature occurs. All the data observed and forecasts are made available to the districts via the „central system" and can be viewed through various graphs, tables and maps.

PRIMARY RWS (LEFT) ALONG A FLEMISH ROAD AND SECONDARY RWS (RIGHT) ALONG A WALLOON ROAD

These components are also supplemented by a thermal mapping system to provide a more comprehensive decision support tool to the local manager. The thermal mapping (the thermal impressions were initially made with infrared thermometry using a vehicle operated on the network) makes it possible, within a homogenous climatic area, to determine simultaneously with local observations, under 3 standard sets of circumstances



FORECAST THERMAL MAPPING FOR FLEMISH ROADS



REAL-TIME THERMAL MAPPING OF WALLOON ROADS

(overcast, clear sky or intermediate), the coldest and hottest areas of the road network.

In the Flemish region, these maps indicate for each weather condition the relative temperature (compared to an average temperature) of the road surface along the network, using a color-coded scale corresponding to increments of 1° Celsius. By combining these relative temperature maps with the forecasts made for each homogenous climatic area represented by an RWS, it's possible to establish a forecast (24 hours) thermal map of road surface temperatures.

In Walloon—where thermal impressions are partially updated every year—relative temperature maps are linked to the data observed by the RWSs to provide a real-time thermal map of the road network. These maps are also used by the traffic management centre to inform road users of the existence of colder areas.

In the case of the Walloon region, all of these functionalities are grouped together in an application called Météoroutes. A new version of this application was developed (since 2004) using web technology to improve the accessibility and presentation of the data. This evolution made it possible to integrate new sources of forecast data (such as radar images and infrared satellite images, which provide a good view of cloud cover movements) and also a portion related to interventions in the field (organization and execution). Road and motorway districts now have a single, centralized application making it possible to consult real-time meteorological data, short- and medium-term forecasts, and the management of field operations, all at the same time.

3.3. EVALUATION OF WINTER MAINTENANCE MEASURES

Cost and benefits of winter maintenance activities—measurement of effectiveness

All data regarding winter maintenance activities (forecasts, decisions, actions carried out, human resources and equipment used, work done by private contractors and salt consumption) are recorded daily in the districts. This information is then gathered by territorial or central divisions so as to present, every month for the entire winter period (October to April), all statistics re-

OVERVIEW OF THE INITIAL TECHNICAL INSPECTION OF SPREADERS (FOR WET (UP) AND DRY (DOWN) SALT SPREADING) – WALLOON REGION

garding winter maintenance (road network to be maintained, means used, ice melter consumption, cost).

"Consumption" indices are currently used (see § 2.3 and 4.2).

Practices leading to additional cost reductions or to better environmental preservation—Methods to decrease the use of ice melters while maintaining service levels

The logging, analysis and reporting of data regarding the spreading of ice melters (quantities of salt, human and material resources used, costs, etc.) encourage all the players involved to contribute to saving money and the environment.

Yearly debriefings and additional training are also frequently organized between successive winter seasons.

Since 2000, with its new contracting system for winter maintenance with the private sector, the Walloon road administration has updated the fleet of spreaders operated on its roads. Today, the new (wet) spreaders owned by private companies are supposed to allow for more accurate salt spreading adapted to road conditions. However, before a multi-year contract is started, each machine must undergo a technical inspection to evaluate its technical characteristics and performance in terms of spread width and accuracy of dosing.

Assessment of the maintenance—payment regulations

Interventions are mainly assessed as part of network inspections as well as in the analysis of the information collected by each district.

EXAMPLE OF A COLOR-CODED WING FORECAST AVAILABLE ONLINE (EXCERPTED FROM HTTP://WWW.MIL.BE/METEO/)

Maintenance work is paid on an hourly basis according to the number of work hours.

3.4. ROAD SAFETY AND INFORMATION

Information for road users—Use of information technologies

The Belgian Air Force's weather section (WING) publishes bulletins on the Internet with weather forecasts relating to road conditions.

Regional road administrations also provide traffic information from their traffic management centers (three in Belgium). These centers control and manage traffic (sometimes including public transportation) around some cities and along regional road networks.

Within these centers, data is collected using the following means:

- Visual display of traffic: several hundred cameras placed in strategic locations along the network allow for traffic conditions to be monitored in real time.
- Counting devices: vehicle counting on motorways is usually done with the help of counting loops or specially designed cameras.
- User calls: roadside emergency telephones are placed at 2 km intervals along motorways. As well, call numbers are specifically devoted to calls from users wishing to report an event that may present a hazard or hinder traffic.
- Automatic Incident Detection
- Information on road works
- Weather information and winter maintenance: the Road Weather Information Systems of the Walloon and Flemish road administrations collect various types of data from the RWSs and, thanks to forecasts and thermal mapping, provide a valid decision-making tool for managers at the traffic management centre. Information about the spreading actions taken by districts is also sent back to the traffic management centre.

The traffic management centers circulate information to road users through various channels. As the information provided must be adapted to drivers' needs (real-time information, to prepare a journey, etc.) the following means are commonly used:

Variable message signs (VMS): traffic signs are a useful means of communication between road managers and road users.

Traffic information concerning motorways in the Flemish region (excerpted from http://www.verkeerscentrum.be/) -----: congestion; -----: dense traffic; -----: normal traffic; ----: no data; road works.

Variable message sign

- Radio and RDS-TMC system: radio broadcasters work closely with traffic management centers.
- Websites:
  http://www.bruxellesmobilite.be
  http://www.verkeerscentrum.be/
  http://routes.wallonie.be/trafiroutes

Locally, in particularly sensitive and dangerous areas, fog detection systems are used along the road, connected to variable message signs or light signals.

International exchange of road information

The automatic exchange of information between adjacent regions regarding traffic management is organized based on a standard European protocol (OTAP system).

4. ONGOING RESEARCH AND STUDIES FOR THE IMPROVEMENT OF WINTER MANAGEMENT

As each regional administration develops its own winter management policy, the following chapters will present a (non-comprehensive) list of the most interesting studies and projects currently underway in the regions.

4.1. NEW TECHNOLOGIES

The road administration in the Flemish region has already equipped one-third of its spreaders with an automatic control system programmed using geographical coordinates as well as a tool to guide drivers based on features specific to each route. Spreaders with GPS antennae were purchased making automatic spreading with this in mind. This is a further step towards monitoring the environmental and budgetary effects of spreading activities as well as towards increasing road safety.

Furthermore, the first steps have been taken to implement a coordinated winter management system; such a system should be linked to a database connected to geographical interfaces.

The Brussels-Capital region road administration has produced a thermal map of its entire road network and plans to install several Road Weather measuring Stations.

In Walloon, another project is also in the initial stages, this one regarding the real-time positioning (GPS) of spreaders out in the field. In 2005, the Walloon region began a review of a data exchange standard protocol and the design of a common GPS signal transmission box so as to be able to manage data from various models of spreaders, mostly privately owned and accordingly each one operating with its own control box. The deployment of such a system (on a total of 300 machines) will be completed in winter 2009-2010. A visualization and operating system, called IRIS, was developed at the same time. It is composed of a "Map" module (for real-time tracking and route management), a "History" module (route and data associated with the service delivery) and a "Statistics" analytical module.

IRIS – REAL-TIME MAP MODULE

BELGIUM

A subsequent phase is planned to allow for the more automated management of data relating to both the services delivered by private operators and those regarding salt stocks.

4.2. NEW MANAGEMENT APPROACHES

The Flemish administration also plans to establish a new service level plan and include in the maintenance contracts it signs with private contractors an outcome obligation, the latter to be based on user satisfaction.

Since 2005, the Brussels-Capital region also manages the spreading of ice melters on 72 km of off-street bicycle paths. This activity has grown significantly as cyclists expect winter maintenance similar to that practiced on roads. The goal is to make bicycle paths usable within 24 hours of a winter shower. The width of the bicycle paths requires the use of special vehicles. Studies are also underway to provide for snow removal on walkways, diversion parking lots, etc.

The Walloon road administration wants to develop quality standards and performance indicators associated with the harshness of winter. To this end, it uses two major computer programs: Météoroutes and NEVE, as well as a winter harshness road index (WHRI).

Météoroutes is the name given to the Road Weather Information System (see § 3.2). The NEVE computer tool is made available to the winter service coordinator and allows the latter to manage all issues associated with winter service with four categories of information: repositories, services rendered by the private sector and by the road administration, de-icer management, and statistics.

It is crucial for a road manager to quickly analyze whether the means (human and material resources) developed for winter maintenance are adequate in view of the meteorological reality. To this end, a winter harshness road index is calculated via Météoroutes at the end of each month and for each of Walloon's 51 Road Weather measuring Stations (primary and secondary).

The following formula is applied to quantify the harshness of winter:

WHRI = 1.07 g + 2.1 n

where g is the number of days of frost on the road surface (= effective days with a road t° ≤0°C) and n is the number of days of snow with a road t° <0°C. The factor of 1.07 is supposed to take into account the inaccuracy of weather forecasts; the factor of 2.1 is based on the hypothesis that a snow removal operation costs on average twice as much as a simple spreading.

This index is then used to link winter maintenance activities and their cost (NEVE report) to the harshness of winter (Météoroutes report), and then establish a cost-quality ratio.

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BRUSSELS-CAPITAL REGION – SNOW REMOVAL ON A BICYCLE PATH (JANUARY 7, 2009)

CANADA-QUEBEC

1. DEMOGRAPHICS AND ROADS

Located in the northeastern portion of North America, Québec opens onto the Atlantic Ocean and extends from the border with the United States to the Arctic.

Geologically speaking, Québec can be divided into three major regions: the Canadian Shield, essentially composed of granite and ancient gneiss; the Lower St. Lawrence clay plain; and the extension of the American Appalachian Range, mostly composed of sedimentary rock. Québec's geography is relatively flat, rarely exceeding 900 meters in altitude. The northern portion of Québec presents tundra vegetation, with soil resting on more or less continuous permafrost. Further south is a taiga zone (299,900 km2), followed by the boreal forest, home to highly diversified wildlife and vegetation (761,000 km2).

Québec's river system is extensive and covers a total of over 355,000 km2. It can be divided into two distinct systems: one running east towards the Atlantic Ocean via the St. Lawrence River and its estuary, and one running west and north towards James Bay and the Hudson and Ungava bays.

The St. Lawrence River, which is 3,260 km long and has an annual flow of 12,600 m3/s (near the city of Québec), is a true point of entry to the North American continent.

FIGURE 1 – QUÉBEC ROAD NETWORK

The St. Lawrence River, which is 3,260 km long and has an annual flow of 12,600 m3/s (near the city of Québec), is a true point of entry to the North American continent. It is on the shores of this river that most Québecers have chosen to live. Although Québec is a pluralistic society, where various cultures live in close contact, 78% of its population speaks French. The inhabited portion of Québec is less than 1,000 km from the major urban and industrial centers of the northeastern United States, constituting a pool of over 100 million inhabitants.

Table 1 – Demographics and land area

Population of Québec	8.3 million inhabitants
(80% live in cities)	Life expectancy at birth
Men – 80.2 years	Women – 84.1 years
Population of the Communauté métropolitaine de Montréal (greater Montréal area)	3.9 million inhabitants(1)
Land area of Québec	1,667,712 km2
Population density	6.4 inhabitants per km2

(1) 62% in the cities of Montréal, Longueuil and Laval.

In Québec, jurisdiction over transportation matters is shared by the federal and provincial governments. The road network is under the jurisdiction of the gouvernement du Québec, which entrusts the responsibility to the ministère des Transports, de la Mobilité durable et de l'Électrification des transports (the Ministère), while the marine, air and rail sectors fall mainly under the jurisdiction of the federal government.

The towns and municipalities of Québec (1,133 in all) are responsible for maintaining public roads that are used by local vehicles and pedestrian traffic, that is, the streets, avenues and boulevards serving their respective inhabitants.

Table 1A – Québec towns of 100,000 inhabitants and over (2017)

Montréal	1.8 M inhab.
Québec	0.539 M inhab.
Laval	0.429 M inhab.
Gatineau	0.281 M inhab.
Longueuil	0.245 M inhab.
Sherbrooke	0.165 M inhab.
Saguenay	0.145 M inhab.
Lévis	0.145 M inhab.
Trois-Rivières	0.136 M inhab.
Terrebonne	0.113 M inhab.

The Ministère has established a road classification system, which serves as the basis for the day-to-day management of the network under its responsibility. This system makes it possible to categorize and group together roads based on their function and importance. This functional classification of the network is in accordance with those in effect in other Canadian provinces and in the United States.

The roads thus classified are used to link together the main concentrations of population, equipment and lands of national and regional importance (Table 2).

Except for the local network, for which Québec's municipalities are responsible (107,000 km), these roads (Table 3) all fall within the Ministère's jurisdiction.

Table 2 – The Ministère's functional classification

Classification	Characteristics
Autoroute network	All autoroute infrastructure.
National network	Interregional roads and those connecting major agglomerations (> 25,000 inhabitants).
Regional network	Links secondary agglomerations (5,000 to 25,000 inhabitants) and major agglomerations.
Local distributor network	Connects small agglomerations (< 5,000 inhabitants) to larger agglomerations.
Local network	Connects small agglomerations to one another and provides access to private property.
Network for accessing resources	Leads to logging and mining areas, hydroelectricity works and Crown recreational and conservat ion areas.

Table 3 – Network maintained by the Ministère (2015)

Network	Length(1)	Mean
AADT(2)	Autoroute	6,019 km
13,689(3)	National	9,027 km
3,980	Regional	5,525 km
3,245	Local distributor network	7,835 km
1,590	Access to resources	2,385 km
260	Local	107 km
N.A.	Total	30,898 km

(1) Length: Weighted kilometer (two lanes)
(2) AADT: Average annual daily traffic. The data do not take local urban traffic into account.

2. CLIMATE

From the 45th parallel along the south and up to the far north, Québec covers 15 degrees of latitude. Its cold, humid climate is largely due to its northern maritime location. Québec's 1,667,712 km2 territory has

four types of climate, with wide temperature and precipitation variations.

The arctic climate in the far north is marked by a harsh, very cold, dry winter and a short thaw season. In Kuujjuaq, for example, the duration of the frost-free period is only 82 days. Recorded precipitation is low and does not exceed 541 mm per year. This is the lowest in Québec.

The subarctic climate, between the 50th and 58th parallels, typically consists of long, very cold winters and short, cool summers. Precipitation is scarce. The average annual temperature in Chapais and Sept-Îles is close to the freezing point.

The most populous regions of Québec, which are south of the 50th parallel, have a continental climate, characterized by hot, slightly humid summers and cold, rather long winters. The thermal amplitude of this climate is approximately 30°C, and precipitation is abundant throughout the year, usually exceeding 900 mm annually.

The maritime climate of eastern Québec is shared by the Îles-de-la-Madeleine. This climate consists of long but fairly mild winters and short, warm, rainy summers.

Other climate characteristics

- The ground freezes for at least four months to a depth varying from 1.2 m to 3 m. In some areas, the frost period can even last from September to May;
- Winter is the longest season. It affects all of Québec's territory. Depending on the region, it can last on average 18 to 25 weeks, and the number of days of snowfall varies from 70 to over 120;
- Québec receives on average 280 cm of snow every year. In some mountain areas, accumulation can even reach up to 6 m.

Table 4 - Temperature and precipitation(1)

	Montréal (alt. 36 m)	Québec (alt. 64 m)	Baie-Comeau (alt. 21 m)	Fermont (alt. 600 m)
Ave. annual T° (°C)	6.6	4.6	2.7	-3.0
Ave. T° in January (°C)	-10.1	-12.0	-13.3	-22.1
Ave. T° in July (°C)	21.2	19.3	16.4	13.5
Days without frost (T° > 0°C)	213	192	178	118
Annual rainfall (mm)	833	900	787	535
Annual snowfall (cm)	172	272	297	291
Days with snow (n)	78.4	100.5	106.8	-

(1) Climate normals (1981-2010)

3. WINTER ROAD MANAGEMENT

3.1 LEGISLATIVE AND NORMATIVE FRAMEWORKS

The Act respecting Roads provides the framework that guides the Ministère in carrying out its mission. This framework addresses the sharing of road network management with the municipalities. In particular, it establishes the Ministère's jurisdiction over roads, decreed by the gouvernement du Québec, and defines the powers and obligations associated with the management of those roads.

Service levels

During snow removal operations in Québec's larger cities, priority is given to the larger roads (boulevards and main arteries) so that people can move around safely and public transit services can be maintained. After that, priority for snow removal operations is given to feeder roads, which connect residential streets with the main arteries, and to streets near schools, daycare centres, hospitals and public services. Snow removal

operations are later carried out in residential and local streets. As a general rule, snow removal operations start when the snow accumulated on the ground exceeds a predetermined threshold.

In the winter period, the Ministère determines the service levels for the road network under its responsibility based on two main criteria: the functional classification of the network and the average winter daily traffic (AWDT).

Table 5 – Determination of service levels

Functional classification	AWDT	Service level
Autoroute	-	Clear road(1)
National road	> 2,500 ≤ 2,500	Clear road(1) Partly clear road(2)
Regional road	> 2,500	Clear road(1)
	≤ 2,500	Partly clear road(2)
Local distributor network and roads providing access to resources	> 2,500	Clear road(1)
	from 500 to 2,500	Partly clear road(2)
	≤ 500	Road with a hard snow base(3)

(1) Roadway whose traffic lanes, including shoulders, are free of snow and ice over the entire width.

(2) Roadway whose traffic lanes are free of snow and ice over a width of 3 m in the straight sections and over a width of 5 m in critical areas.

(3) Roadway whose traffic lanes and shoulders are on a hard snow base at most 3 cm thick. Under favourable weather conditions (T°air > 3°C for more than 48 hours), the level of maintenance is brought up to partly clear road.

In order to deal with certain special situations, the Ministère designates some parts of its network as ecoroads. An ecoroad is a road that is maintained using an alternative form of maintenance during the winter in order to reduce the environmental impact of de-icers on areas sensitive to road salts. This form of maintenance gives precedence to increased scraping and limited used of abrasives in critical areas to ensure road network safety.

The establishment of a winter ecoroad is based on three general principles:

1. The primacy of road safety: the safety of all road users, no matter whom, must remain a priority.
2. Endorsement by the community: any initiative to establish and implement an ecoroad must be supported by the community (the population and elected officials).
3. The possible repercussions on one or more vulnerable areas.

Quality standards and performance indicators

The Ministère uses various measures to improve its performance in terms of winter maintenance. For example, it does an annual assessment focussing exclusively on the performance of private sector snow removal on sections of the road network (see 3.3). Also, he is using a winter severity index to establish an objective comparison of winter severity and the consequences on maintenance efforts deployed during a given winter. Based essentially on the weighting of certain climatic conditions (T°, rain, snow, etc.) with impact on maintenance operations in the network, the index makes it possible to compare certain operational data (amount of de-icer used, number of hours worked) and to measure performance.

Materials

The extent of the road network and the need to ensure safe, effective supply of the many service points found there prompted the Ministère to establish a contractual agreement through which it entrusts a single service provider with the supply of a major portion of the sodium chloride (rock salt) it uses to maintain the network. In particular, this agreement sets the technical characteristics that this product must meet for the Ministère's requirements. These characteristics are drawn from, among other things, the standards in effect in North America.

Table 6 – Grading range specifications for de-icing salt

Grading screen	Minimum (passing %)	Maximum (passing %)
12.5 mm	—	—
10 mm	95	100
5 mm	20	90
2.5 mm	10	60
630 µm		11

Table 7 – Grading range specifications for abrasives

Grading screen	AB-5 (passing %)	AB-10 (passing %)
10 mm	-	100
8 mm	100	-
5 mm	85-99	95-100
2.5 mm	1-15	-
1.25 mm	0-5	0-70
630 µm		0-50
315 µm		0-35
160 µm		0-15
80 µm		0-5

AB–5: Suited to abrasives composed of crushed stone.
AB–10: Suited to abrasives composed of sifted sand, crushed stone or crushed or uncrushed gravel.

In terms of regulations, on April 3, 2004, under the Canadian Environmental Protection Act, the Government of Canada published a code of practice inviting road administrations to implement measures to reduce the environmental damage caused by road salt. Québec has its own environmental protection legislation containing, in particular, regulations governing the elimination of waste snow.

Furthermore, when it adopted its Sustainable Development Act (2006), the gouvernement du Québec instituted, within public administrations, a management framework to ensure that powers and responsibilities would be exercised in the pursuit of sustainable development. That is the backdrop against which the Ministère drew up the Stratégie Québecoise pour une gestion environnementale des sels de voirie (Québec strategy for the environmental management of road salts), urging the various network managers (cities, municipalities and the Ministère) to draw up plans for the environmental management of road salts. The Ministère's plan specifies objectives and actions to be taken with regard to the environmental management of road salts.

Motor vehicles

In Québec, the Highway Safety Code (HSC) governs the use of vehicles on public roads and, in particular, sets the framework for the use of chains and studs on tires on the road network. Their use is authorized from October 15 to May 1 and is limited to certain vehicle

FIGURE 2 – PICTOGRAM IDENTIFYING A TIRE DESIGNED SPECIFICALLY FOR WINTER DRIVING

categories. In 2008, a regulation on the use of tires designed specifically for winter driving took effect in Québec. This affects all registered passenger vehicles in Québec, including taxis, from December 15 to March 15, inclusively. The tires of such vehicles must display a specific pictogram on their sidewalls certifying that they are designed for winter driving (Figure 2). Otherwise, they must be equipped with studs in accordance with the Regulation respecting the use of non-skid devices.

Table 8 – Studs, chains and winter tires – Authorized vehicles

Device	Authorization
Studs	Commercial and passenger (1) vehicles with a gross vehicle weight not exceeding 3,000 kg
Chains	Emergency and snow removal vehicles
Winter tires	Passenger vehicles(1) and taxis registered in Québec, including rental passenger vehicles

(1) Transportation capacity of not more than 9 people.

Equipment assigned to network maintenance

Like all motor vehicles in Québec, the equipment assigned to winter road maintenance and its use is subject to the HSC and to various other laws and regulations:

- The Act respecting owners, operators and drivers of heavy vehicles establishes a framework for road

transportation by introducing an administrative system for the registration of owners and operators of heavy vehicles, assigning safety ratings, as well as imposing penalties in the event of offences;

- The Regulation respecting the hours of driving and rest of heavy vehicle drivers forces the operators of heavy vehicles to submit to monitoring of the hours of driving and work performed. Accordingly, to ensure public safety, clear roads of snow accumulations and spread de-icers or abrasives, the driver of a snow removal truck may drive up to a maximum of 13 hours per work shift.

Table 9 – Snow removal 🕮 Hours of driving and rest 🕮 Main measures

Obligations	Rules
Driving prohibited if the total number of hours of driving is:	> 13 hours
Driving prohibited if the total number of hours worked is:	> 14 hours
Minimum number of consecutive hours of rest before starting a new work shift	≥ 8 hours

Hours of driving: Hours during which the driver is in control of a heavy vehicle with the engine on.
Hours of work: Period of time that includes the hours spent driving and performing various duties.

As well, the owners or operators of heavy vehicles must perform a visual and auditory inspection of certain components of their vehicle to prevent accidents that could be caused by the vehicle's poor condition;

- The Vehicle Load and Sizes Limits Regulation applies to road vehicles and combinations of road vehicles primarily to ensure the safety of road users and protect road infrastructures (bridges and roads). This regulation sets various standards limiting, among other things, the size and load of road vehicles operated on public roadways. In addition, in the spring, to take into account the reduced load-bearing capacity of the road network during the thaw period, it imposes load restrictions in accordance with three defined areas (Figure 3). Depending on changing weather conditions, the start and end of the load restriction period may be moved up or pushed back.

FIGURE 3 - LOAD RESTRICTION AREAS

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Ministère's organizational structure consists of an Operational Management Directorate, to which report 59 service centres, spread over 12 different territories of Québec (territorial branch). These territorial units benefit from significant autonomy in terms of resource management and they work together with the regional and municipal organizations in the community.

The responsibility for the network's maintenance falls directly on the service centres, which manage contractual agreements either with the private sector (for 66.1% of the network) or with the interested municipal corporations (for 13.7%). The Ministère and its teams maintain 20.2% of the network. For everyday maintenance work, the Ministère, like the private sector, generally prefers to use three-axle trucks. However, heavy (four-axle) trucks can be used to meet specific operational needs (increased de-icing autonomy, use of specialized equipment, etc.) while complying with the regulations applying to heavy vehicles.

Table 10 – Snow removal truck

Basic characteristics	Specifications	
	3 axle (6x4)	4 axle (8x4)
Rear axle capacity	18,000 kg	20,860 kg
Front axle capacity	9,000 kg	18,000 kg
Gross vehicle weight	30,000 kg	39,000 kg
Motor	Diesel: 305 kW minimum	Diesel: 330 kW minimum
Rear suspension	Pneumatic	Pneumatic
Transmission	Automatic	Automatic
Electronically controlled spreading system	Yes	Yes
Spreader	9 m3	11 m3
Snowplow wing	3,657 mm	3,657 mm
One-way snowplow	3,657 mm	3,657 mm
Front mount	Yes	Yes
Light signals	Yes	Yes

These vehicles are called "multifunctional" because they make it possible to (alternately or simultaneously) carry out both snow removal and de-icing operations on the network. This multiple functionality facilitates the synchronization of operations and ensures increased effectiveness. These vehicles are also equipped with an electronic spreading regulator and light signals specific to snow removal operations. These measures, designed primarily to increase the visibility of maintenance operations throughout the network, are also used on other types of maintenance equipment (such as graders and snow blowers) that can be found on the Ministère's primary network.

Naturally, snow removal contracts are awarded by the Ministère according to a regulated process. Such contracts are awarded either through a call for tenders from the private sector or through negotiations with municipalities, which are also network managers (107,000 km).

These contractual agreements, based essentially on performance measurement, are established for one year and include a renewal clause, generally for two additional years. Because the tendered (or negotiated) price is all-inclusive, efficient service providers (municipalities) can keep the contractual agreement with the Ministère for a maximum period of three years. This approach allows the contractor to better distribute the financial risks inherent to the performance of the contract and the severity of the winters. These agreements generally provide that the service provider will supply the materials necessary for the maintenance of the network (salt and abrasives).

For specific needs, the Ministère rents snow removal trucks with operators. At the operational level, the latter report directly and only to the Ministère and are integrated into existing maintenance teams. These contracts are based on a minimum number of operating hours and the successful bidders do not supply the materials.

Operational management

The partnership on which the Ministère relies for the network's maintenance is based on clear expectations regarding the results. Accordingly, depending on the type of network maintained, each contract (administrative and technical documents) contains specific requirements regarding snow removal, de-icing and network patrols.

The Ministère monitors the entire network for which it is responsible to ensure compliance with the prescribed expectations. To structure and guarantee consistency in network monitoring practices, the Ministère, through its territorial branches, has a winter maintenance monitoring plan. It defines the guidelines given to the operational units and ensures uniform oversight of road network winter maintenance work, which is done by both service providers and Ministère employees (force account).

The Ministère uses the Guide des bonnes pratiques d'épandage (Guide to best spreading practices) and to the spreading charts in that guide. Those tools enable operational staff to make informed decisions in the context of materials spreading, and to standardize practices. The spreading charts (Figure 4) incorporate the principal road weather notions, and are based on the experience and empirical knowledge that the Ministère's maintenance personnel has acquired. They thus provide a solid foundation with respect to routine winter maintenance operations.

Road closures

To ensure motorists' safety, the Ministère may decide to temporarily prohibit traffic from using its network.

FIGURE 4 – EXCERPT FROM THE SPREADING CHARTS

This decision is always taken jointly with emergency preparedness authorities, municipalities and the police forces concerned. The Ministère alone can decide on the right time to re-open roads to traffic.

Cooperation between network managers

The diversity of winter issues encountered across Québec and Canada, and the multiplicity of stakeholders involved, require ongoing coordination efforts. In order to promote the exchange of knowledge and training in this field, the Ministère works closely with other network managers facing similar issues. This cooperation gives rise to fruitful exchanges within various transportation associations, such as the Transportation Association of Canada (TAC), the World Road Association (PIARC) Technical Committee on Winter Service and the Association québécoise des transports (AQTr).

It is in this spirit of pooling knowledge and experience that the Ministère, in partnership with the AQTr, leads the Table d'expertise sur la viabilité hivernale. Members of this group come from different backgrounds (clients, industrial partners, educational institutions, professional associations, etc.). Its purpose is to share practices in the field and in particular the results of the work of the PIARC Technical Committee on Winter Service.

ROAD WEATHER AND TRAINING

Stationary road weather stations

Thanks to their open-architecture design, the stations, developed entirely by the Ministère, offer much flexibility regarding the selection of the various sensors of which they are composed. This type of station accurately measures the main meteorological and road parameters that have an impact on variations in road conditions. Using a 3m frost depth probe, also designed by the Ministère, the station provides data for the decision-making process related to the vehicle load restriction period on the Québec road network during spring thaw (see Figure 3). Two types of stations have been developed: one offers a complete range of measurements (see Table 11); the second is a streamlined, less expensive station limited to measuring only certain targeted road and weather parameters that are likely to be needed for specific operational problems.

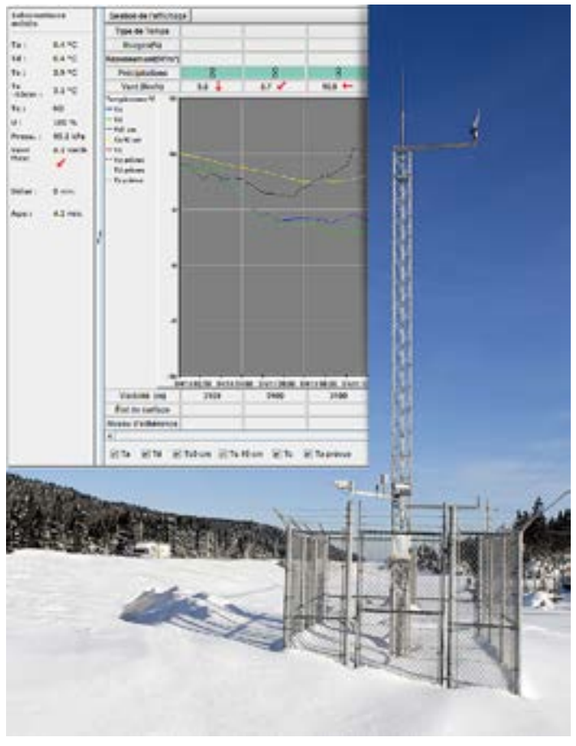

FIGURE 5 – STATIONARY ROAD WEATHER STATIONS AND THE RWIS SYSTEM

FIGURE 6 – MOBILE ROAD WEATHER STATION

Today (2017), the Ministère has a network of 53 road weather stations, nearly half of which are equipped with 24-hour cameras that relay weather and road conditions throughout the network to the maintenance staff. To make it easier to manage and interpret the incoming data, a computerized system (SMR) is available to back up the work of the staff assigned to operations. A forecasting segment (weather and road conditions (TS)) is displayed on the SMR system, even though weather forecasting is entrusted to the private sector through tender calls.

Mobile road weather stations

Also designed by the Ministère, mobile road weather stations (Figure 6) supplement the information collected by the stationary stations. This equipment, which is installed on the Ministère's some 230 patrol vehicles, provides an accurate portrait of the road surface's behaviour along the entire route travelled by the patrol vehicles. Interpretation of the various parameters that are measured allows vehicle operators to anticipate the formation of ice on the road and adjust the spreading strategy if required, based on the data collected.

Table 11 – Functionalities Stationary and mobile stations

Functionalities available	Stationary station	Mobile station
Wind intensity/direction	Yes	No
Visibility	Yes	No
Precipitation intensity/type	Yes	No
Air temperature (Ta)	Yes	Yes
Relative humidity (U)	Yes	Yes
Atmospheric pressure (P)	Yes	Yes
Dew point calculation (Td)	Yes	Yes
Surface conditions - freezing point (residual brine)	Yes	No
Road surface temperature (Ts)	Yes	Yes
Residual brine concentration	Yes	No
Frost front propagation in the road pavement	Yes	No
Geographical positioning of data	Yes	Yes
Data display - real time	Yes	Yes
Data retrieval for analysis	Yes	N/A
Fixed cameras	Yes(1)	N/A

(1) On some stations

To support the deployment, annual training sessions are offered to the staff assigned to operations within the Ministère, in particular through the intermediary of a network of road weather trainers. The Ministère has also developed a training program on winter road maintenance in cooperation with the Association québécoise des transports (AQTr); it contains a specific segment on road weather conditions. These technical training sessions are available to everyone working on winter maintenance in Québec.

3.3 EVALUATION OF WINTER MAINTENANCE MEASURES

The vastness of the territory and the diverse nature of Québec's economy have made the province's road network both elaborate and very much in demand. The openness of the economy, the volume of exports to the North American market and the provision of natural resources and manufactured products from outlying areas are all factors that explain the road network's vital role in Québec's economic development.

Table 12 Québec's economy in numbers

Value of exports (2016)	$80.3 B
Largest trading partner	United States
Proportion of international exports to the United States (2016)	71% ($57.1 B)

To ensure sustainability in the winter season, the Ministère allocates over $260 million annually to direct operations on the road network under its responsibility. Aware of the economic and social issues associated with snow removal on the network and the challenge of managing such operations in the context of scarcity of resources, the Ministère undertakes:

- with the snow removal industry, to reposition and define a better balance with respect to the associated risk. This new balance consists in reducing contract lengths and using different contract management modes during the transition periods between seasons, as well as implementing technological tools, such as GPS, etc.;
- to measure the compliance of the services provided by contractors with the requirements and specifications set out in contractual documents. Accordingly, each winter maintenance route assigned to a private service provider under contract with the Ministère (≈ 66% of the network) is evaluated according to a grid containing 19 quality criteria relating to snow removal and de-icing, communication and collaboration, as well as compliance with the deadlines specified in the contract. Through this approach and those associated with the surveillance and monitoring of its network, the Ministère ensures that, in the field, the highway system's maintenance continues to comply with very high quality requirements so as to ensure safe, functional transportation. Accordingly, since 2005, the Ministère has integrated this indicator into its annual management report, a report that is tabled, in compliance with the provisions of the Public Administration Act, with the President of the Québec National Assembly.

Table 13 – Indicator – Results achieved

Result	Rate of compliance with winter road maintenance requirements
2013-2014	89.7%
2014-2015	94.0%
2015-2016	96.6%

Note: According to the grid designed to interpret the results, a rate of between 90% and 95% shows that the contractor met the requirements effectively.

3.4 Road safety and user information

With the Ministère's participation, the Société de l'assurance automobile du Québec (SAAQ) conducts an annual awareness and advertising campaign on winter road safety. On the theme "in winter, slow down and keep a safe distance", the general goal of the campaign is to encourage road network users to be prudent by raising their awareness of the risks inherent to driving in the winter, which requires changes to habits. The means of communication include messages broadcast on the radio, news tickers on weather and traffic bulletins, animated banners on the Web and the signage on the whole road network. The Québec 511 website and Radio circulation are also tools that are used.

The Ministère also offers the public and users of the road network the ability to get information on the condition of the highways during the winter and on traffic obstacles. To facilitate access to that information at all times, it provides them with a mobile application, telephone service and the Québec 511 site.

FIGURE 7 - TERMINOLOGY FOR ROAD WEATHER CONDITIONS

The terminology for winter road conditions describes road surface and visibility conditions separately. It also indicates the presence of snow drifts that are likely to affect traffic on the network. This approach provides more detailed information and more accurate descriptions of road conditions on the road network covered by the broadcast system. A four-colour code (black, yellow, white and red) provides a visual representation of the road conditions that drivers need to take into consideration before travelling.

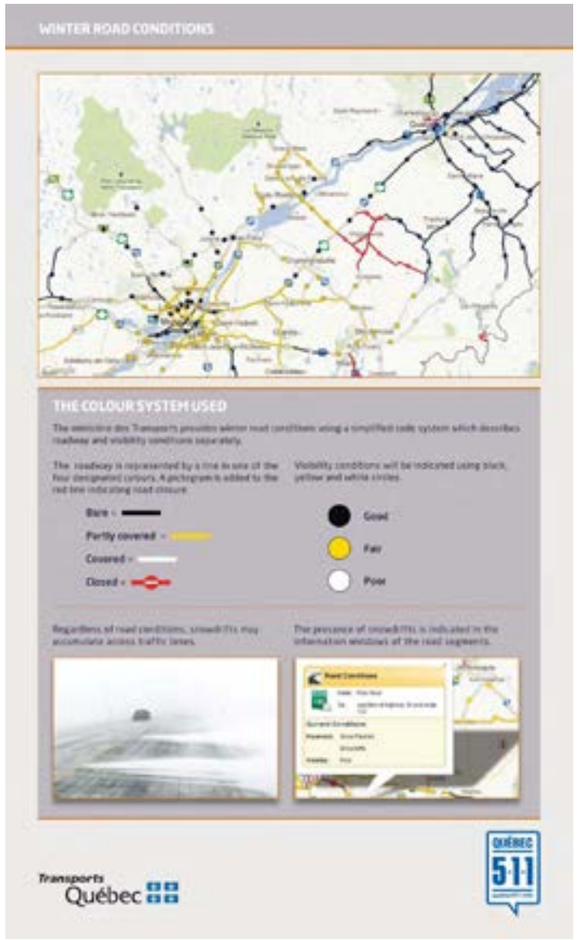

FIGURE 7A - TERMINOLOGY FOR ROAD WEATHER CONDITIONS

On the 373 road segments located across the Ministère's network, information on road conditions is gathered using smart phone technology at least once a day and whenever a change in conditions is observed (Figure 7A). The mobile application feeds data into the winter road conditions system (système des Conditions routières hivernales (CRH)), which quickly redirects the information to users, as well as to the general population, through Service Québec 511 Info Transports, and to various specialized media outlets.

Concerned with providing quality information to users of the winter road conditions service, the Ministère has implemented a mechanism to verify the information delivered to the population in order to detect potential anomalies in the system and obtain feedback on which it can take corrective action.

The Ministère is responsible for the highway system's operation and, as such, must assume a significant share of the responsibilities associated with the assistance to be given to users in trouble and management of the risks associated with such emergency situations. With this in mind, the Ministère has published a guide for members of its staff who are called upon to help road users in trouble, containing various tips on effective and safe ways to act in such circumstances.

Integrated traffic management centres

Intelligent transportation systems (ITS) are new technologies used to improve the management and operation of transportation systems as well as services for road users. Such systems are used within the Ministère via the integrated traffic management centers (ITMC). Through improved knowledge of the network's usability, these centers increase user safety and the free flow of traffic, in particular during the winter period when conditions can be difficult. Combined with various management tools, the centres' cameras and variable message panels provide real-time information directly to users on problems arising on the network in winter.

As well, on networks with specific difficulties (e.g., high-volume and high-speed traffic; major wind corridor), a simple preventive approach with the user is possible using pace vehicles or through the establishment of

devices prohibiting access to portions of the network deemed risky.

4. ONGOING RESEARCH AND STUDIES

4.1 NEW TECHNOLOGIES

Today, technology offers a range of means to obtain accurate real-time information from the road network. Like many network managers, the Ministère examines the possibilities offered by this new method by implementing projects of a technological nature. Here are a few examples:

- the deployment and use of on-board equipment for vehicles used in particular for snow removal operations and network surveillance. The purpose of the latter is to record all road and/or operational information (geo-tracking, spreading, scraping, etc.), and to transmit that information in real or non-real time to an integrated network management system (vehicular data communication (VDC));
- the utilization of an experimental stationary, open-architecture road weather station to measure the full potential of various sensors and technologies applicable to the field and available on the market;
- development and testing of an automatic system for detecting slippery road surfaces so that warnings can be sent to users and operational teams;
- experimentation with the potential of various sensors for assessing road surface conditions;
- experimental use of an automatic brine sprinkling system;
- development of tools and guidelines concerning the use of humidified de-icing materials.

FIGURE 8 – NON-INTRUSIVE SENSORS

4.2 NEW MANAGEMENT APPROACHES

The Ministère is in the process of examining the management approaches currently used. To this end, it is trying out new contractual approaches aimed at sharing risks differing from those generally identified for snow removal and de-icing work on its network. In this way, using adapted technology, the Ministère hopes to better control maintenance costs on its network and foster the integration of new contractors entering the snow removal market.

For the Ministère, imagination and research constitute dynamic responses to the challenges presented by Québec due to the breadth of its territory and the harshness of its climate. It is by focusing on these elements in particular that the Ministère plans to improve the performance of transportation systems.

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Bourque, A., and G. Simonet. "Québec," in Vivre avec les changements climatiques au Canada, 2007 edition, D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush (eds.), Government of Canada, Ottawa (Ontario), 2008, pp. 171-226.

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CHINA

1. DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

FIGURE 1 - LOCATION OF CHINA

China is a socialist state under the people's democratic dictatorship. Monetary unit in China is Renminbi (RMB). One Dollar was 6.5480 RMB in September 2017. The basic information about China is following:

Table 1 – Basic information about China

Area	Land area	9634057 km²
	The sea area of jurisdiction	3 million km²
Population	1354.04 mil. people	
Length of coastline	Continental coastline	18 kilo km
	Islands' coastline	14 kilo km
Geographic coordinates	Latitude (Beijing)	39.9°N.
	Longitude (Beijing)	116.3°E.

Source: http://english.gov.cn/; Annual Report of Economy and Development in 2012

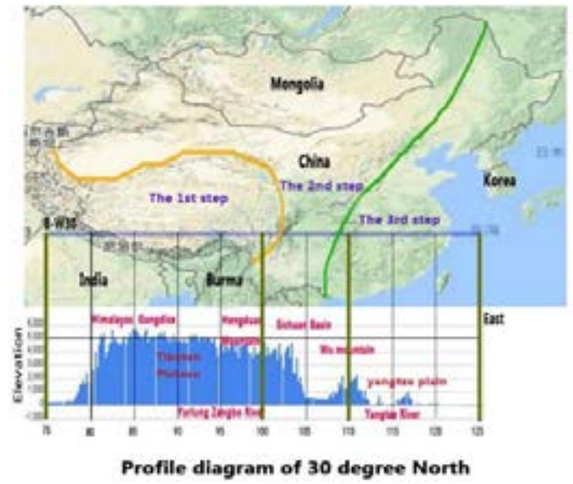


FIGURE 2 - MULTI-TERRAIN MAP OF CHINA

China is topographically high in the west and low in the east, showing the ladder-like distribution which gradually declines from west to east. Elevation of three steps are respectively above 4 kilometers, 1-2 kilometers and below 5 hundred meters (Fig. 2).

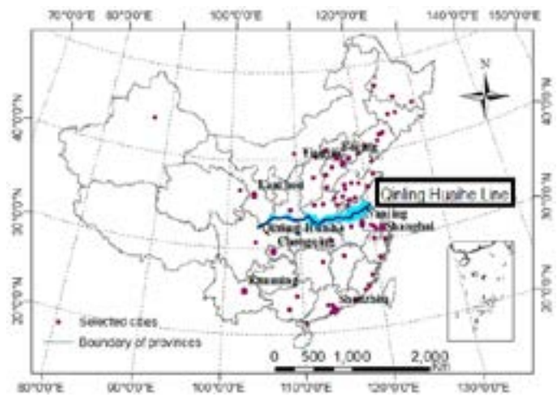


FIGURE 3 - THE QINLING HUAIHE LINE

China has the highest mount "Mount Everest" with the height of 8843.44 meters and the greatest plateau "Tibetan Plateau" with an average elevation above 4000 meters which is called "the roof of the world".

The Qinling Huaihe line is a reference line used by geographers to distinguish between Northern and Southern China (Fig. 3).

China's administrative unit is the government and National People's Congress (NPC) with elections every 5 years. There are 23 provinces, five autonomous regions, four municipalities and two special administrative regions (SARs).

1.2 ROAD NETWORK AND TRAFFIC

In China, road levels are classified according to two different categories: Functional levels and Administrative levels. They are following:

Table 2 – Road type 1— Functional levels

Road Type	Length of Road
Freeway	4.7 mil. km.
Level 1 roads	98.6 kilo km.
Level 2 roads	371 kilo km.
Level 3 roads	422.7 kilo km.
Level 4 roads	3202.9 kilo km.
Gradeless highway	47.0 kilo km.

Table 3 – Road type 2 — Administrative levels

Road Type	Length of Road
National roads	354.8 kilo km.
Provincial roads	313.3 kilo km.
County roads	562.1 kilo km.
Village roads	1147.2 kilo km.
Township roads	2250.2 kilo km.

Source: Ministry of Transport: The 2016 yearly National Statistic Gazette of the Ministry of Transport. (NSGMT)

As the length of highways is increasing, transportation volume is also growing rapidly. According to NSGMT, by the end of 2016, there have been 840 thousand passenger vehicles and 13.52 milo. freight vehicles, which contributed to 15.4 billion passenger capacity and 33.4 billion freight volume.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

China's climate is dominated by dry and wet monsoons, which makes for clear temperature differences between winter and summer. In summer, influenced by warm and moist winds from seas, most parts of the country are hot and rainy. In winter, the cold and dry winds blowing from the continental land-mass towards the seas are prevalent, so most parts, especially north parts of the country, are cold and dry.

2.2 EFFECTS OF MAIN WINTER EVENTS

In ten years between 2005-2014, Chinese transportation construction was booming with the miles of traffic length leaping from 1.93 mil. km to 4.46 mil. km. Accompanied by increasing transport volume, the number of traffic accidents is increasing too. Variations in traffic safety parameters like road friction coefficient and driving sight distance are largely decided by the weather (Fig. 4). Bad weather has always been one of the main factors leading to traffic accidents (Guicai Ning et al, 2016).

The existing research conducted by Harold (1988) has explained that the possibility of traffic accidents on rainy days is 2-3 times higher than that on sunny days but in snowy days, it will increase to as much as 14 times. And the study conducted by El-Basyouny (2012) has shown that daily snowfall and precipitation has a positive correlation with car crash which can be seen in table 4.

FIGURE 4 - POSSIBLE DANGEROUS ON ROADS IN SNOW DAYS

Table 4 – Bad weather effects on transportation

Index Weather	Rain	Snow	Hail	Fog	Wind	Sand
TNTA	248939	19932	43	16742	1644	483
Ratio of TNTA (%)	86.5	6.93	0.01	5.82	0.58	0.17
TELTA/1 million RMB	1424.39	161.45		233.91	8.86	2.11
Ratio of TELTA(%)	77.8	8.82		12.78	0.48	0.12
AELEA/RMB	5721.85	8100.11		13971.40	5390.11	4367.33
TNIA	297737	24097	57	20497	1765	537
Ratio of TNIA	86.38	6.99	0.02	5.95	0.51	0.16
ANIEA	1.2	1.21	1.33	1.22	1.07	1.11
TNDA	67174	6198	19	7854	599	220
Ratio of TNDA	81.86	7.55	0.02	9.57	0.73	0.27
ANDEA	0.27	0.31	0.442	0.469	0.364	0.455

TNTA: The total number of traffic accidents
AELEA: Average economic loss in each accident
ANIEA: Average number of injuries in each accident
ANDEA: Average number of deaths in each accident
TELTA: Total economic loss of traffic accidents
TNIA: The total number of injuries in accidents
TNDA: The total number of deaths in accidents
(Guicai Ning et al, 2016)

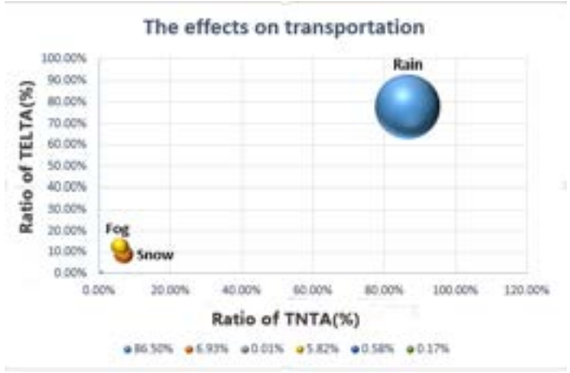


FIGURE 5 –WEATHER EFFECTS ON TRANSPORTATION

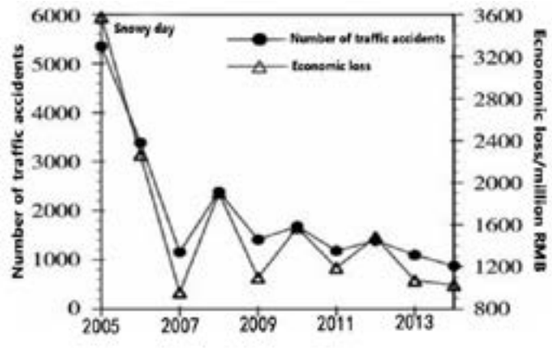


FIGURE 6 - VARIATION IN THE NUMBER OF TRAFFIC ACCIDENTS AND THEIR ECONOMIC LOSS

After analyzing the characteristics and economic loss of traffic accidents (Fig. 5), the meteorology department and traffic bureau cooperate with each other to reduce costs of the accidents.

From the Figure 6, we can see that the number of accidents decreased annually except 2008. Influenced by La Nina event in the Tropical Pacific Ocean in 2008, China experienced a once-in-a-century ice storm. The great freezing rains and snows in the south of China caused a countless economic loss and more than one billion people were affected. (Guicai Ning et al, 2016).

2.3 Statistics on temperature, icing, precipitation

China has a large span of latitudes. The amount of heat from solar radiation received by a place in China depends on where it is. According to large amounts of temperature data, China is divided into 5 temperature zones (Fig. 7) and each of these zones has its own climate. We select 12 cities to give a brief but representative description of China's climate.

Different places have different amount of snowfall. The study conducted by Danwu Zhang et al (2016) has shown the distribution of snow in China during the past five decades.

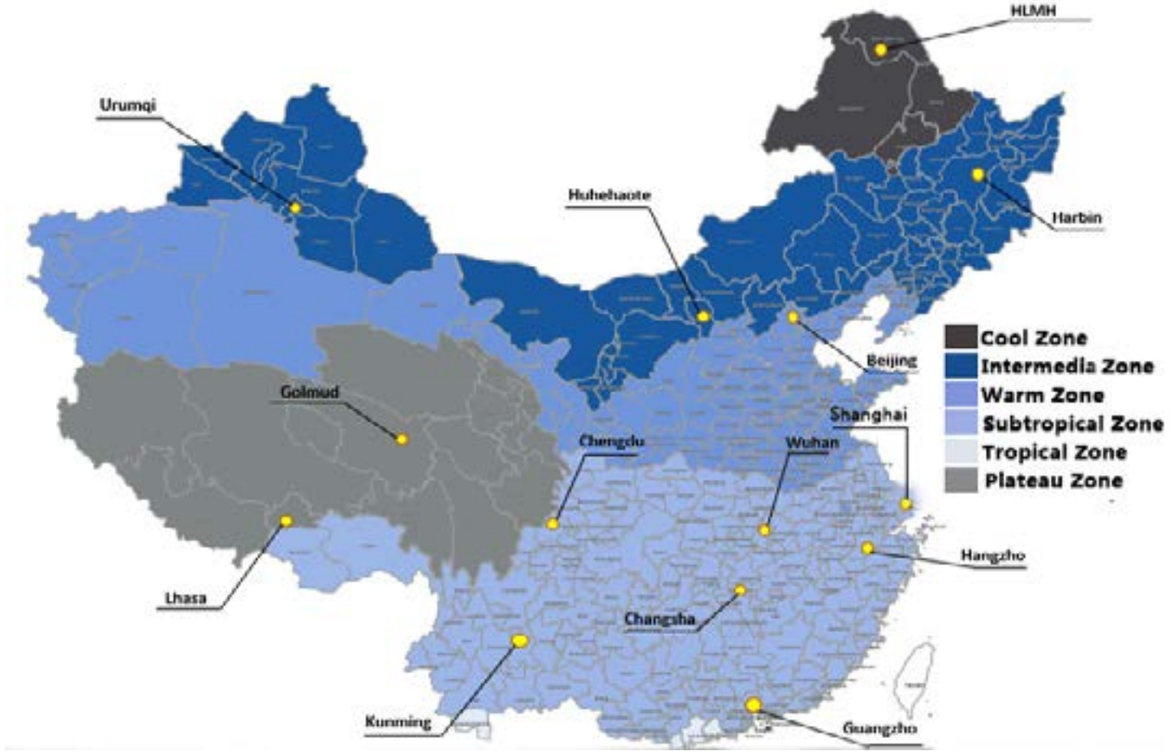


FIGURE 7 - THE TEMPERATURE ZONE OF CHINA

Table 5 –Temperatures and precipitations in China (34-year avg., 1980 - 2014)

Station	Temperature/°C		Precipitation/mm		Freezing Index/°C days
	TMAX	TMIN	PRCP	EMXP	AFIA
Mohe	25	-36	491	57	3575
Harbin	26	-23	558	43	1660
Beijing	32	-6	628	161	220
Hangzhou	33	6	1463	93	3
Wuhan	32	4	1364	140	5
Chengdu	31	6	628	82	0
Guangzhou	33	13	1920	166	0
Lhasa	23	-7	286	69	101
Urumqi	29	-15	186	72	1089
Huhehaote	28	-15	480	103	878
Shanghai	31	3	1194	125	3
Kunming	25	3	596	81	0
Changsha	34	4	1465	97	4
Golmud	24	-13	39	21	732

TMAX: The max of the yearly average temperature *TMIN: The minimum of the yearly average temperature*
PRCP: The year average precipitation *EMXP: The max precipitation of the whole year* *AFIA: Average freezing index*

As we can see in Figure 8, there are four places which have more snowfall than others: the north and the east of northeast China, north of Tianshan Mountains, Tibetan Plateau, the middle and lower reaches of the Yangtze River (Danwu Zhang et al, 2016). In these areas, we should pay much attention to traffic safety during winter days.

3 WINTER ROAD MANAGEMENT

3.1 HISTORY AND BACKGROUND OF SNOW AND ICE CONTROL PROGRAMS

According to the latest Technical Specification of Maintenance for Highway in China, measures of preventing roads from being damaged by snow and ice should be based on local situations. When it comes to major engineering projects or some important roads vulnerable to ice and snow, emergency plans should be built up in advance.

Winter season in Heilongjiang province is cold and lasts a long time. Every year from the beginning of November to the following March, Heilongjiang province is covered constantly by snows (Bing Leng et al, 2015). Based on the specific situation in this province and combined with maintenance requirements on roads of

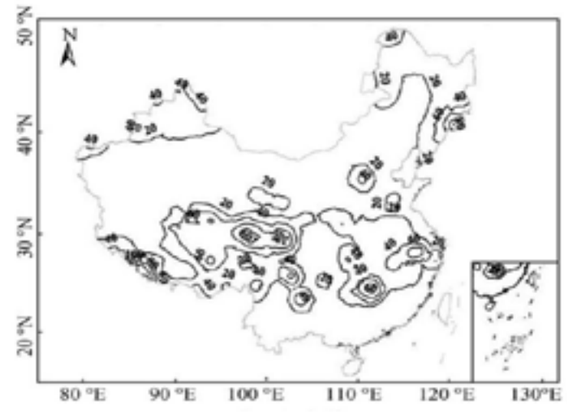


FIGURE 8 – THE SNOWFALL DISTRIBUTION OF CHINA (PICTURE REDRAWN FROM J TSINGHUA UNIV)

some other areas in winter, the following article briefly summarizes China winter road management. The general process is shown in following flow chart: (Fig. 9)

3.2 BEFORE MAINTENANCE

3.2.1 Road surface managing

Road Surface Roughness (RSR) refers to the deviation of the road unevenness which is considered to be an

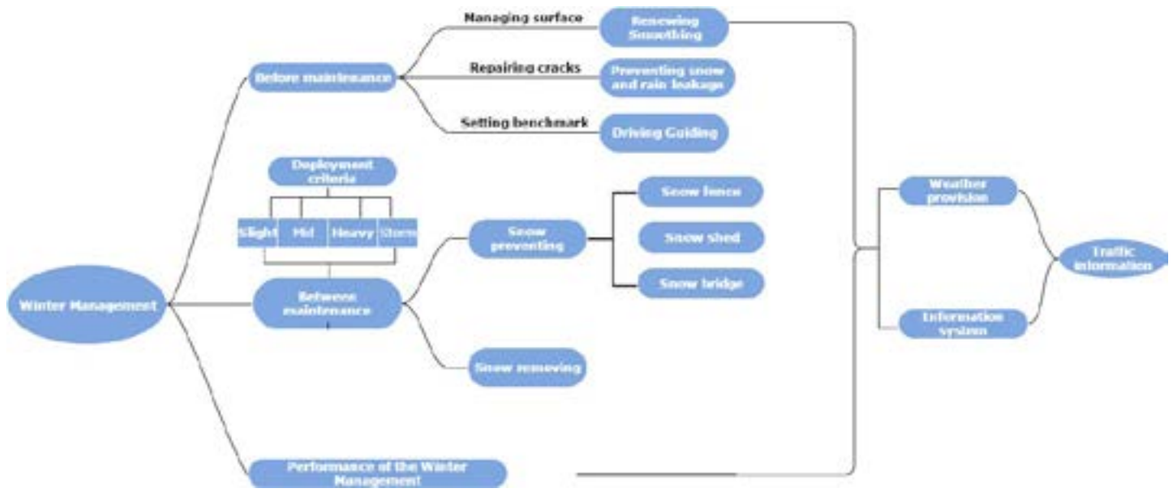


FIGURE 9 – FLOWCHART OF PROCEDURES FOR ENSURING ROAD TRAFFIC SAFETY IN SNOW DAYS

FIGURE 10 - TURNING OVER AND SIDE SLIPPING

important parameter in the road evaluation and road surface construction. It is closely related to traffic safety and comfort and determines the size of the impacting force on roads. If the road is uneven, vehicle vibration will occur, which increases driving resistance and affects driving speed and safety. Meanwhile, the effect of vibration can also exacerbate wear and tear between roads and vehicle tires.

Especially in winter, vehicles on roads are easily out of control due to vibrations and then accidents like roll -over and rear-end collision will happen. (Fig. 10)

To decrease the vibration effect, China takes some measures to ensure the pavement smoothness before winter road maintenance. These measures consist of controlling top elevation of roads, improving constructions of Asphalt Mixture Surface Course etc. (Fig. 11)

3.2.2 Road cracks repairing

Crack is one of the most common damages to roads which cannot only affect road appearance and driving comfort, but also cause structure damages and short lives to roads. Especially on snowy days, melted water will flow into cracks among roads. Under the influence of thermal expansion and contraction effect, the expanding water will enlarge cracks and thus cause destruction of the whole pavement structures.

FIGURE 11 - GROUND LEVELING AND CONSTRUCTIONS OF SURFACE

FIGURE 12 - ROAD CRACKS REPAIRING

Crack tackling procedures will be divided into two stages: crack detecting and crack repairing. (Fig. 12)

3.2.3 Benchmark setting

In sections of roads that are susceptible to snow damages, guide poles are set on flanking sides of the roads as traffic guide signs. (Fig. 13)

3.3 DURING MAINTENANCE

3.3.1 Level of Service (LOS)

According to classification of China meteorology department, the size of snow can be divided into four

FIGURE 13 - ROAD GUIDE MARK

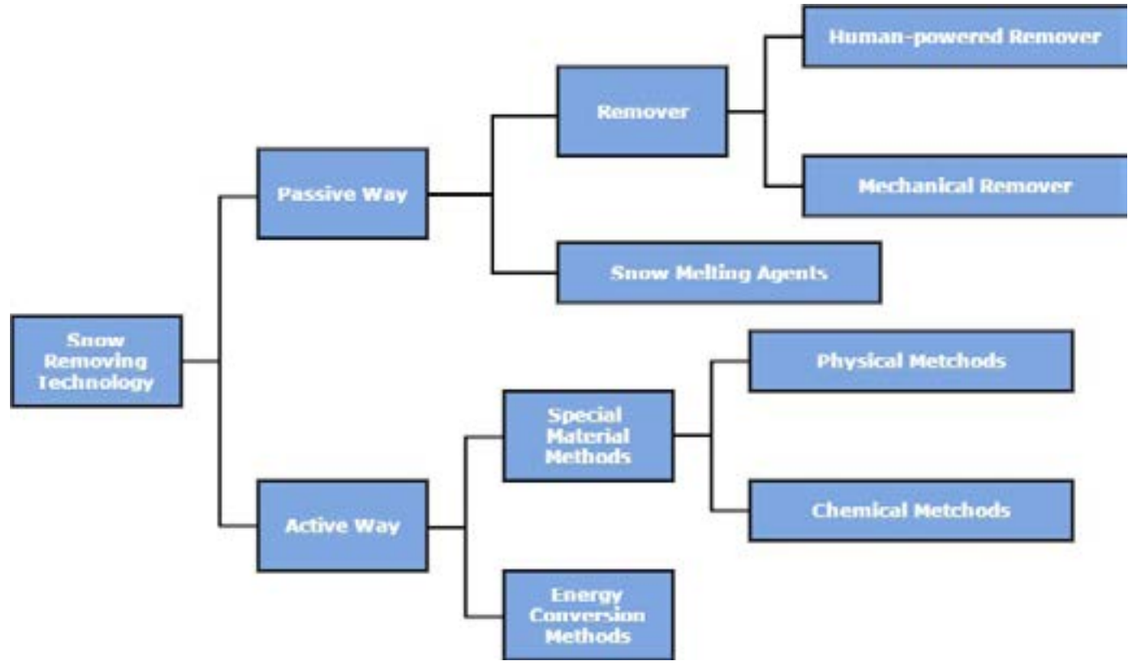


FIGURE 14 - PROCEDURES DURING MAINTENANCE (PICTURE REDRAWN FROM HIGHWAYS & AUTOMOTIVE APPLICATIONS, 2013)

types: slight snow, moderate snow, heavy snow and blizzard. The depth, pressure, shape and density of snow can all be factors affecting qualities of road surface. Hence different level of snow causes different level of destruction. The Ministry of Transportation sets deployment criteria for each type of snow level. The LOS initiated in Shijiazhuang city is as follows (Table 7).

Table 6 – The definition of snow levels

Snow level	Definition			Warning type
	P 12(mm)	P 24(mm)	SD(cm)	
Slight snow	(0.1,1)	(0.1,2.5)		
Moderate snow	(1,3)	(2.5,3.5)	3.5	
Heavy snow	(3,6)	(5,10)	5.0	
Blizzard	(6,∞)	(10,∞)	8.0	

P12: Precipitation in 12 hours P24: Precipitation in 24 hours SD: Snow depth

Table 7 – Criteria for deploying snow- and ice-control operations

Snow level	Waring type	Emergency measure								
		EmA	EmB	EmC	EmD	EmE	EmF	EmG	EmH	EmI
Slight snow		■	■							
Moderate snow		■		■		■	■			
Heavy snow		■			■	■	■	■	■	
Blizzard		■			■	■	■	■	■	■

Table 8 – Emergency measures of each level

Classes	Emergency measure
EmA	All the personnel and vehicles are in place.
EmB	The third department decides to start.
EmC	The second department decides to start.
EmD	The first department decides to start.
EmE	All the snow melting vehicles should load the snow melting agent in less than two hours.
EmF	Strengthen road cleaning, the inspection of bridge and drainage.
EmG	Professional snow melting group begin to implement snow melting in less than one hours.
EmH	The city's snow cleaning headquarters organize their personnel and machinery to carry out the snow clearance.
EmI	The governments, the snow control headquarters, the units at all levels pool the strength of all quarters into snow clearance.

(Bing Leng et al, 2015)

3.3.2 Snow preventing

Snow fences

The speed of snow and wind drift will be blocked when it flows across snow fences, forming a weak-wind zone. In these zones, most of snow deposits before snow fences while only a little flows across the top of fences, which will reduce snow damages to the roads.

Snow sheds

Snow shed is a type of rigid snow-supporting structure for avalanche control. It can be made of steels, prestressed concrete frames, or timbers.

Snow bridge

Snow bridges may superficially look similar to snow fences, but they act differently. Snow fences are built vertically and accumulate snow on their downwind side, while snow bridges are slanted or horizontal and hold snow on their top side.

Snow-breaking woods

Snow-breaking woods (Fig. 15) slow down the snow drift and catch snow grains carried by winds, preventing them from blowing to roads. This snow-proof measure is cost-efficient and environmentally friendly. The location of woods and its planting numbers should be decided by wind direction and snow level.

Snow fence *Snow shed*

Figure 15 – Snow control measures

Figure 16 – People are moving snow

3.3.3 Snow removing

People-using removers

During every winter in Harbin, people use spades to shovel snows, moving them from the middle of the roads to sides (Fig. 16). This way is flexible but also has some disadvantages: long operating time, low work efficiency and consuming large amounts of manpower. Besides, traffic can also be affected by these working people.

Plow snow remover *snow removal grader*

Figure 17 – Snow removing machines

Mechanical-using removers

When temperature is low and snowfall is big, using mechanical devices to remove snow and ice is very efficient. From 1980 of the 20th century, the development of snow removers was started in China and today there have been three widely-adopted categories: plow snow remover, rotary snow remover and snow removal grader (Wei Hao et al, 2008) (Fig. 17).

Table 9 – Different kinds of snow removers

Categories	Qualities and advantages
Plow remover	Low cost, high reliability
Rotary remover	Multifunction
Road grader	Small workspace

Except in winter, these devices will be put aside in the most part of the year and their short lifespans also need high maintenance costs.

Snow melting agents

Large grains of snow can be removed by mechanical devices but for those small ones, it doesn't work. Snow-melting agents are efficiently applied to reduce those small snow grains. These agents can lower freezing point of snow. The solid forms of snow grains turn into water and flow into drainage systems. Nowadays, common snow melting agents can be classified into three kinds (Tab. 10).

Figure 18 – Snow-melting agents

Figure 19 – Spraying snow-melting agents

Table 10 – Different kinds of snow-melting agents

Categories of anti-freezing agents	Advantages	Disadvantages
Chloride salts agents	Low costs; abundant sources;	Pollution and corrosion
Non-corrosive agents	Non-corrosion; non-pollution	High costs; Large amounts of oxygen
Organic activity agents	Non-corrosion; non-pollution; high efficiency; convenient; low costs	

Using special materials

Snow melting technology of elastic road is to add some special materials in the laying periods of road (Zhibin Han, 2013). In winter, weight of cars and their pressure will stimulate those special materials, making them generate heat, thus melting snows. Though this way is advanced, these special materials cost so much. It's so difficult to maintain such roads and as time goes on, roads will be damaged and its effect of melting snow will disappear.

Energy conversion methods

Melting snow by energy conversion is the way that we use other forms of energy (geothermal, solar and electric energy, etc.) to generate thermal energy (Zhi-

Figure 20 – Snow-melting roads

bin Han, 2013). And this thermal energy can transfer up along underground pipes to road surface and then melts snows. This snow melting way can be divided specifically into two stages: energy saving and energy emitting. In summer, we can use energy storage device to gather thermal energy and in winter, these energies will be released.

3.4 PERFORMANCE OF WINTER ROAD MANAGEMENT

In December 2011, the completion of Dawu Bridge Group adopted the technology of conductive concrete deicing. The project was located in Hubei province, consisting of two closely tunnel bridges and wiring project, a total length of 3.7 km. It effectively prevented the bridge from icing and ensures the safety passing vehicles.

In November 2012, a viaduct of a highway in Hunan Province used anticoagulant ice material SMA-16 asphalt. It's 120 meters long with two ways and six lanes. The width of a single bridge is 15.75 m.

FIGURE 21 - THE BRIDGE WITH CONDUCTIVE CONCRETE DEICING TECHNOLOGY

FIGURE 22 - THE BRIDGE DECK WITH (LEFT) AND WITHOUT ANTI-ICING MATERIAL (RIGHT)

It can be seen from the contrast of figure 2 and figure 3 that the effect of ice and snow prevention on the bridge deck with SMA-16 is obvious. The bridge without anti-icing material is covered with snow severely, which has great security risks.

3.5 TRAFFIC SAFETY & INFORMATION

Landscapes and climates in China vary from region to region and it's difficult to design any competent system that can accurately report current traffic information.

So each of the following two systems: weather information system and traffic information system has its own disadvantages which requires further development.

3.5.1 Weather information systems

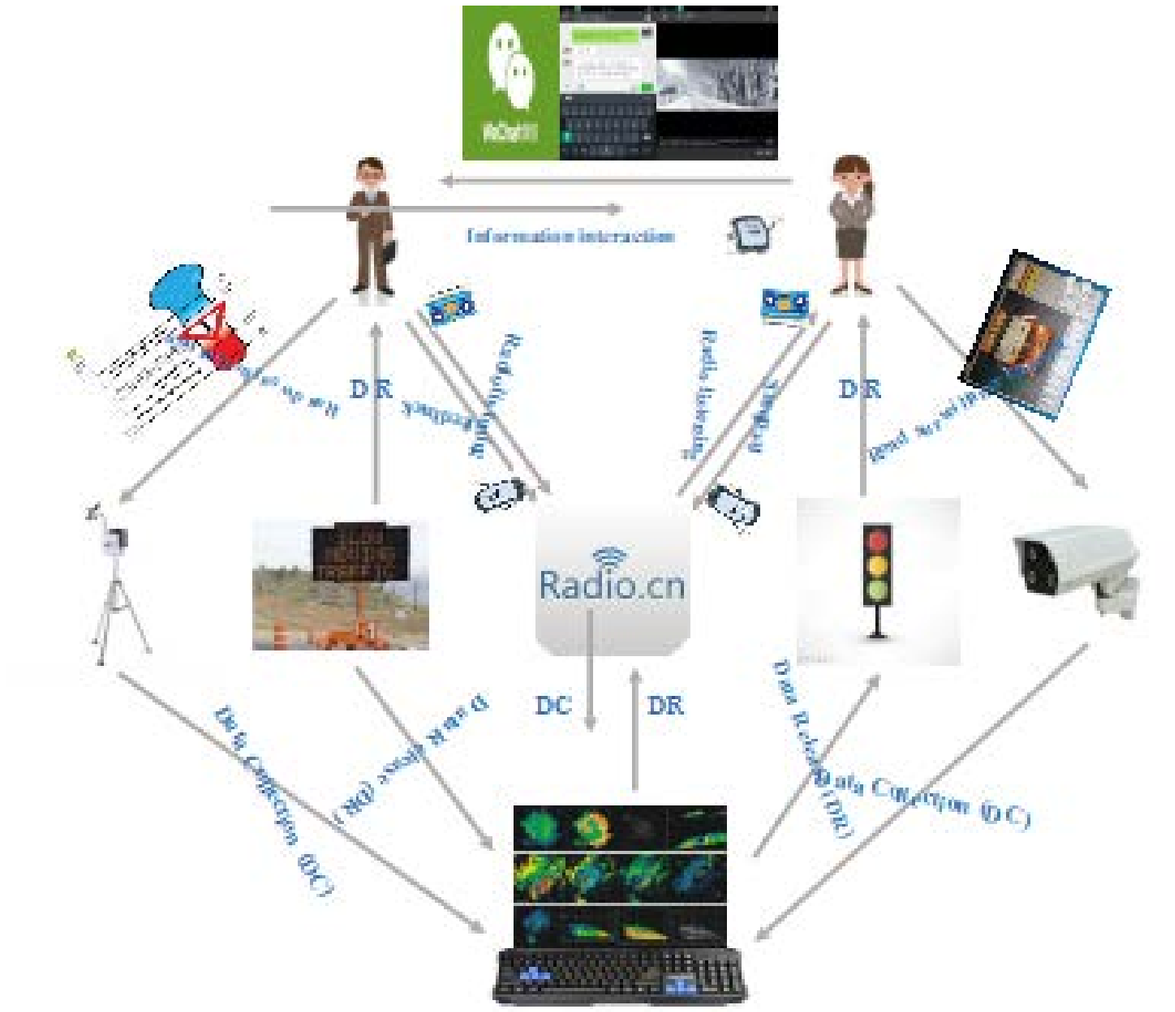
Based on historical data and satellite cloud images, China meteorology administration has been running a portal website which is connected to personal mobile phones. This website can provide you some information about current temperature, precipitation, wind velocity, etc. According to this up-to-date weather information, drivers can change their driving behaviors to avoid accidents.

Due to the fact that traffic accidents always happen in snow days, early-warnings will be presented on this website and different warning colors will be used as a signal to remind drivers to drive carefully.

When it comes to some important routes vulnerable to snow damages, suggestions like driving slowly or choosing other routes will be given to drivers via internet and broadcast.

FIGURE 23 – WEBSITE FOR WEATHER AND ROAD INFORMATION IN WINTER
(Source: http://www.cma.gov.cn/2011qxfw/2011qyjxx/, China Meteorological Administration)

FIGURE 24 – APP FOR WEATHER AND ROAD INFORMATION IN WINTER



Road weather station

Road surveillance camera

Road information displays

Variable message board

FIGURE 25 – TRAFFIC AND ROAD WEATHER INFORMATION SYSTEM

3.3.2 Traffic information systems

In China, information can be conveyed between different objects: person and person, person and machine, machine and machine. With these three combined, an information network is built where people can get traffic information immediately.

In China, Wechat has been the most popular chatting software for some time. As you can see in the picture, information that there is a car accident on Songshan street is sent to your friends when you are chatting. Pictures of Huanghe road has also been uploaded online to warn that the traffic in this road has already been greatly affected by blizzard.

Listening to traffic radio is always an effective way for drivers to get current traffic information. In China, each province has its own radio station which offers abundant traffic information. Traffic radio is also an interactive platform where drivers can call in and report what they see and hear on roads.

4. ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 Further developments of snow-melting agents

Composite types of snow-melting agents are produced by using inorganic and organic salts and a small amount of corrosion inhibitors. Compared with traditional snow-melting agents like sodium chloride, these snow-melting agents have high snow-melting efficiency and can protect the environment at the same time.

Study done by Meng Wang et al. (2014) showed that the organic salts are nearly noncorrosive which can be seen in following table:

Table 11 – Corrosive rate of different kinds of snow -melting agents

Types	Δ M/g	S/cm²	V/()
SA	<0.0001	10.8258	<0.0001
CN	0.0103	12.0760	0.1983
SC	0.0131	11.5180	0.2644
CC	0.0120	9.9982	0.2790

SA: sodium acetate CN: calcium nitrat SC: Sodium chloride
CC: Calcium chloride ΔM: Mass loss of metal during corrosion
S: Metal surface area V: Corrosion rate(Meng Wang et al, 2014)

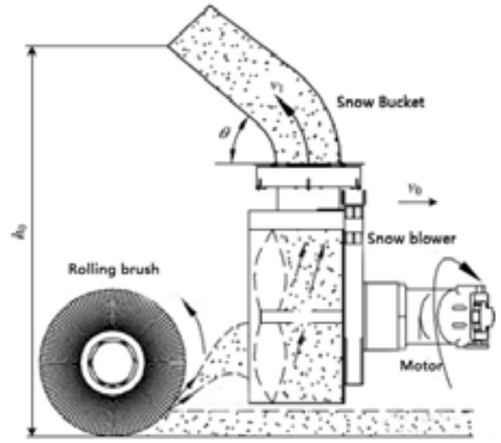


FIGURE 26 - TRACK SNOW REMOVING DEVICE (GUANZHU GUO, 2016)

4.2 ADVANCE IN IMPROVING SNOW REMOVING MACHINES

Snow removing ploughs and rotary casting snow removing devices are commonly used abroad. Limited by their structures, it's difficult for them to clean the snow from the rail surface to the following concrete slab sleeper surface.

Guanzhu Guo (2016) developed an autonomous track snow removing device which integrated the functions of rolling brush to brush snow and wind machine to suck snow. When it works, rolling brush will blow up snows and these snows will be sucked into the wind machine. The schematic diagram of the machine is as follows:

Snow-melting agent emulsion distributor is a new type of snowmelt device. In study conducted by Zhu-

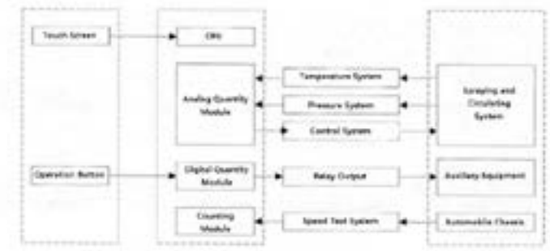


FIGURE 27 – SNOW-MELTING AGENT EMULSION DISTRIBUTOR (ZHUORU YAN, 2014)

oru Yan (2014), an intelligent snow-melting agent control algorithm is analyzed.

Based on this algorithm, ice and snow are melted more rapidly and efficiently. It can also protect the environment.

4.3 CURRENT DEVELOPMENTS ON ROAD MATERIALS AND STRUCTURES

Chemical treatments and mechanical removers have been widely used to remove snow on winter roads. However, both of these two methods have some inevitable problems: strong corrosion, serious pollution and low efficiency. To tackle with these problems, new types of road materials and structures are developed.

4.3.1 Road materials

In study done by Zhaohui Min et al (2017), a new asphalt mixture called epoxy asphalt mixture (EAM) was developed. It used epoxy resin as a modifier to change the thermoplastic characteristic of the binder. Three-dimension unsolvable crosslinking networks created by reaction between binder and curer can provide the mixture with excellent durability, high-temperature stability, fatigue resistance and moisture stability.

In study done by Zhenjun Wang et al (2017), asphalt mixtures incorporating with salt-storage aggregates (SSA) are made from mixing MgO, MgCl2, salt-release materials (SRM) and hydrophobic silicone powder in certain proportion. The self-prepared SSA added to asphalt mixtures can greatly improve the property of asphalt mixtures which can be used in special areas of asphalt pavement, such as ramp and steep slope to greatly overcome disadvantages of conventional snow -melting methods, such as severe environmental pollution and high economic consumption.

Table 12 – The comparison between SSA and AC - 13

Properties	Specification	Test result	
		SSA	AC 13
AD/(g/cm^3)	2.6	2.701	2.714
NPPC/%	15	7.2	10.15
ACV /%	26	18.4	15.02
LAA/%	28	21.8	7.5
WA/%	2.0	0.6	1.32
AWS	4	4	5

AD: Apparent density/(g/cm^3)
NPPC: Needle and plate particle content/%
ACV: Aggregate crush value
LAA: Los Angeles abrasion value/%
WA: Water absorption/%
AWS: Adhesion with asphalt
(Zhenjun Wang et al 2017)

4.3.2 Road structures

Nowadays, China has three types of pavement heating systems: hydronic system, electric heating system and infrared radiant heating system. They are as follows:

Most researches of hydronic system done in China have focused mainly on two aspects. One is to develop models to simulate the heat transfer pavement snow

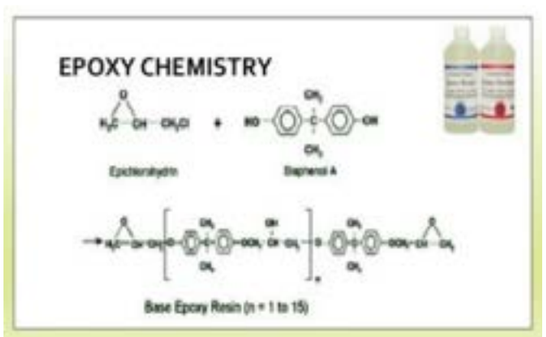


FIGURE 28 – MOLECULAR STRUCTURE OF EPOXY CHEMISTRY

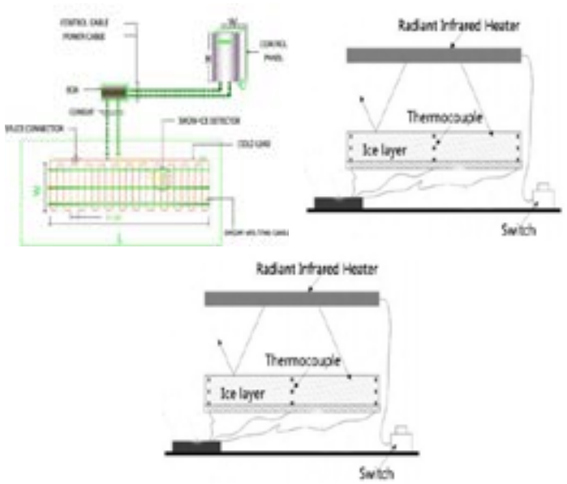


FIGURE 29 – THREE KINDS OF PAVEMENT HEATING SYSTEMS

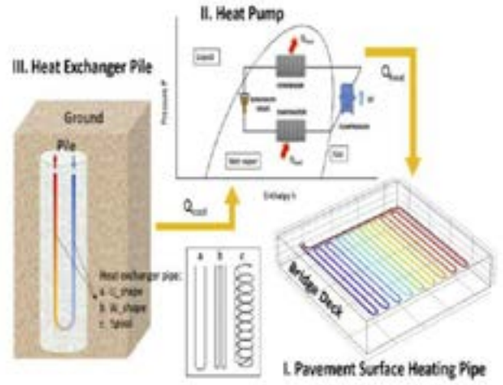


FIGURE 30 – SCHEMATIC DIAGRAMS OF WORKING PRINCIPLE OF GEOTHERMAL HEAT PUMP SYSTEM

melting process and evaluate its performance. The other one is to improve design of hydronic system to increase its work efficiency.

Model developing

In study conducted by Huining Xu et al (2017), a two-dimensional heat and mass coupled numerical scheme is developed to modify the snow melting model proposed by Liu et al.

Chanjuan han and Xiong Yu (2017) carried out a validated computational model to analyze the amount of thermal energy extraction by a single thermal energy exchanger pile installed with different types of heat exchanger pipes.

Design improving

Heat pipe technology used in melting snow is attractive because its features of environmental conservation and low maintenance.

However, the heat pipes need special anti-corrosion treatment against soil and the length should be long enough to reach isothermal layer which means that the prophase investment of these type systems are enormous. In addition, the transportation and installation of these heat pipes, over 50 m long, are inconvenient.

In order to overcome these defects mentioned above, Xiaoyuan Wang et al (2017) have designed an ice and snow melting system using super-long flexible heat

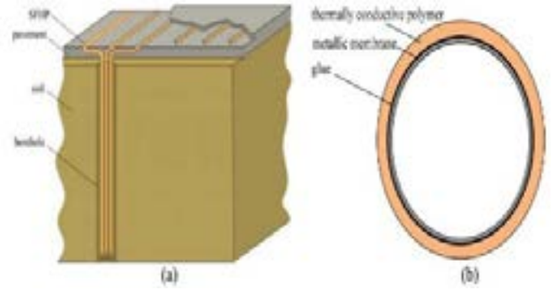


FIGURE 31 – (A) ICE AND SNOW MELTING SYSTEM USING SFHPS; (B) CROSS SECTION IN AN SFHPS

pipes (SFHPs) based on thermally conductive polymer which will reduce cost and make it more convenient to be fabricated, transported, and installed.

4.4 INTELLIGENT SYSTEM OF VEHICLE BRAKE ON ICE AND SNOW ROADS

With the rapid development of artificial intelligence (AI), transportation system is facing a great revolution. The newly developed discipline including data communication, electronic sensing technology, computer science etc. will be applied to change the entire traffic and civil engineering industry.

Braking distance refers to the distance a car moved until fully stopping after braking. In snow days, sliding friction between tire and road surface is very low due to icy roads, especially when tires are totally locked when braking which will change sliding friction to rolling friction. And this rolling friction will inevitably increase braking distance and make drivers take corners sideways and thus cause traffic accidents. In order to avoid this phenomenon, anti-lock braking system (ABS) was devised.

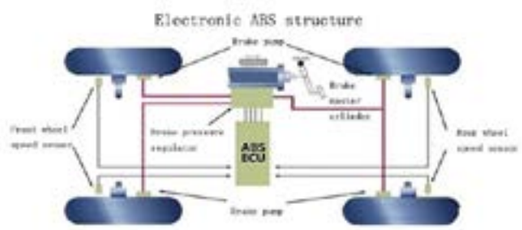


FIGURE 32 – SCHEMATIC DIAGRAM OF ANTI-LOCK BRAKING SYSTEM

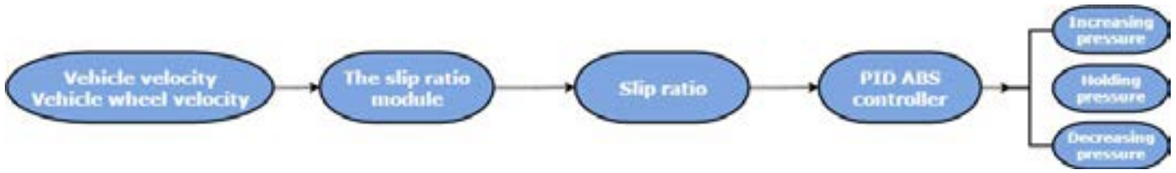


FIGURE 33 – FLOW CHART OF PROCEDURES IN INTELLIGENT SYSTEM OF VEHICLE BRAKE

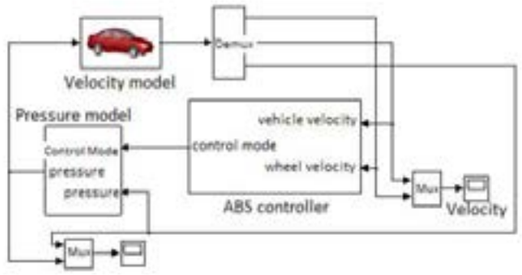


FIGURE 34 INTELLIGENT BRAKING SYSTEM

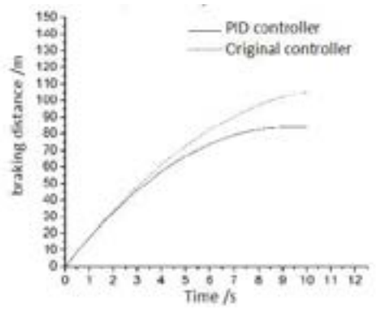


FIGURE 35 – BRAKING DISTANCE

In study done by Lei Zhang and Liping Lei (2017), a logic threshold PID controller is designed to improve the vehicle brake performance on ice and snow roads.

4.5 DISCRIMINATION OF HIGHWAY SNOW CONDITION WITH VIDEO MONITOR

Snow detection in image sequences with video monitor has become an attractive research issue, since it needs no extra on road equipment.

The previous study contains limited comparison and explanation of the chosen methods for classifying road conditions. The study done by Chunyu Zhang et al (2012) gave the video based snow detection area extraction method and extracted its image feature for snow cover from the selected area.

FIGURE 36 – FLOW CHART OF PROCEDURES IN DISCRIMINATING HIGHWAY SNOW CONDITIONS

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1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Figure 1 – position of the Czech Republic in Europe

The Czech Republic is a medium-sized country (78,867 km^2) but densely populated (10.46 million), situated at the center of Europe. The landlocked country borders Poland to the northeast, Germany to the west, Austria to the south and Slovakia to the east. The capital and largest city is Prague (Praha). The country is composed of the historic regions of Bohemia and Moravia, as well as parts of Silesia. Since 2000, the Czech Republic is divided into thirteen regions and the capital city of Prague. The Czech Republic has been a member of the European Union since 2004.

The Czech Republic possesses a developed, high-income economy with a GDP per capita of 84% of the European Union average. The economy prosperity of the Czech Republic relates to the high level and quality of the transport infrastructure. With the density of 0.70 km of roads and motorways per 1 square km the Czech Republic ranks among the leading European countries.

1.2 ROAD NETWORK AND TRAFFIC

Table 1 – Road network

Area	**78,867 km^2**	
Population	**10.46 million**	
Length of roads	Motorways	633 km
	Expressways	329 km
	Roads class I	5,843 km
	Roads class II	14,660 km
	Roads class III	34,118 km
	Amount in full	55,583 km

The road network comprises 633 km of motorways, 329 km of expressways and 54,621 km of regional and local roads, amounting to a total of 55,583 km of paved roads. Road transport accounts for 76.04 % of total freight transport. The national fleet of 4.9 million vehicles includes 4.1 million passenger cars.

Winter season in the Czech Republic, according to the Road Law is the season between November 1 and March 31 of the following year.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The Czech Republic is a landlocked country located in moderate geographical latitudes in the Northern hemisphere. The climate of the Czech Republic is mild but variable locally and throughout the year. The climate differs markedly among the various regions of the Czech Republic, depending on the height above sea level.

2.2 STATISTICS ON TEMPERATURE

The average air temperature is strongly dependent on the height above sea level. When the temperature on the highest mountain in the Czech Republic (1,602 meters) is only 0.4 °C, the lowlands of southeast Moravia can experience temperatures of almost 10 °C. The annual rainfall is also markedly dependent on the height above sea level. If we want to find the rainiest area in the Czech Republic, we would have to look to the highest mountain range with steep slopes facing northwest. The average total rainfall there is in excess of 1,200 millimeters.

December, January and February are counted as the winter months. The coldest of these is January, when even in the lowlands the average monthly temperature falls below 0 °C. If there is any precipitation in winter, it is usually snowfall in the mountains. In the lowlands it can alternately rain and snow. Snow coverage usually lasts for several months at higher altitudes above sea level. However, during March, April and May, there is a sharp increase in temperatures. Snow coverage usually disappears in the mid-spring, even in the highest mountains of the Czech Republic.

2.3 WINTER INDEXES

Winter Index (WI) is a unique system of deep analysis and comparison of road winter maintenance performances and costs. The users of this system are mainly administrators responsible for covering the maintenance costs but also contractors of winter road maintenance. WI exactly describes winter conditions on a selected territory in a period of time and compare the real cost of road winter maintenance.

Road and Motorway Directorate of the Czech Republic uses WI for evaluation of winter maintenance effectiveness and performance of particular centers of motorway management and maintenance in cooperation with a company Cross Zlin and the Czech Hydrometeorological Institute.

WI is a system of analysis and comparison of road winter maintenance performances and costs depending on real meteorological conditions at a defined road and highway network. The main activities that are monitored are:

- salting (or gritting) the roads and consumption of salt and other materials,
- snow removal (plowing),
- inspection routes.

There is direct linkage between current weather conditions and extent of above mentioned parameters.

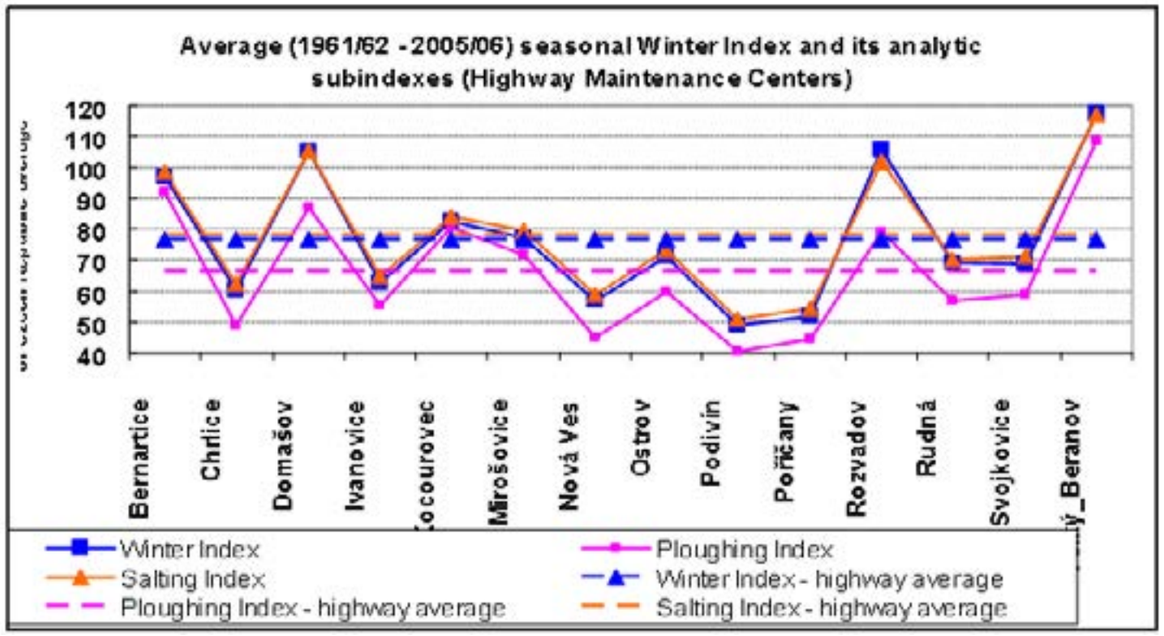

FIGURE 2 – WINTER INDEX AND ITS SUB-INDEXES, COMPARISON BETWEEN DIFFERENT MAINTENANCE CENTERS

When winter conditions become more severe (snowfall, temperatures around zero, freezing rain, ice on the road, etc.) it is necessary to employ more maintenance vehicles and use larger amounts of salt that represent the major item in winter maintenance expenses. WI is a unique tool that enables retroactive control of road maintenance performances and comparison of maintenance level between different centers of maintenance or contractors. Based on this analysis it is possible to detect divergences from the standard level and separate any isolated or long-time anomalies and unjustified raising of costs.

At figure 2 is presented the usage of the winter index in the form of its graphical output. Performance of particular centers of motorway (highway) management and maintenance is evaluated there.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Winter maintenance in the Czech Republic is regulated by Road Law no. 13/1997 and by Ministry of Transport regulation no. 104/1997, valid for act on Road Law.

The Road and Motorway Directorate of the Czech Republic (RSD) performs the winter management and maintenance for 715 km of motorways and for some expressways. The regional administrators manage the winter maintenance for the other roads. In 2004, the RSD published "Winter management and maintenance regime" and in 2007 "Technological procedure for winter maintenance of motorways and expressways".

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Winter maintenance reduces climate and winter conditions effects on road serviceability by their importance. In a winter situation the road administrator eliminates or at least reduces problems in road serviceability according to the schedule set in the winter maintenance plan and regulated by the Road Law.

It means that the road administrator removes snow and ice from roads with the help of special machinery. Snow exceeding 3 cm of height is removed by snow plow. Frost, ice and snow up to 3 cm of height is removed with the help of deicing agents. We distinguish just plowing, just chemical materials spreading, and both activities carried out simultaneously. Separately, we consider regular checks of roads serviceability.

Sixteen Centers of motorway management and maintenance (SSUD) and one Center of expressway management and maintenance (SSURS) are managed by RSD and form the basis of the winter maintenance on the motorway. One center SSUD performs the winter maintenance for roughly 50 km motorways, i.e., for roughly 1,000 thousand km^2 pavements.

Each SSUD equipment and facilities for winter maintenance consist of:

6-8 fully equipped vehicles with spreader dripping brine and with a snowplow;

salt storehouse (NaCl) containing up to 2,000 to 3,500 tonnes. The storehouse is usually designed for the whole year consumption;

brine center which consists of a plant producing brine (aqueous solution of sodium chloride) and two storing tanks and tanks for concentrated solution of calcium chloride (the brine is used for applying on the spread salt);

loader, a mechanism with about 1.5 m3 bucket loading salt into spreaders;

control office in SSUD building with radio connection to working spreading vehicles, telephone and access to meteorological information (cameras monitoring, etc.).

Other facilities and equipment of the centers are shown in "Regime of administration and maintenance". Description of systems related to winter maintenance such as meteorological stations, warning signs and camera systems are shown in "Regime of road signing and marking and facilities administration and maintenance".

Users' requirements are mostly very high. They demand fast and safe use of roads and if possible completely without snow, i.e., "black" throughout their whole length. Demands for maintenance quality, driving comfort, safety and speed are higher and higher.

Road managers try to meet this demand by using high performance equipment, the meteorology agency, installing meteorological sensors, and by performing mutual alerts, etc. Similarly, the use of increasingly better performing spreading materials associated with theses technologies allows the combined use of salt and brine to facilitate the service offering. The ARA also uses inert materials (crushed stone) on a 1.6 km section of Autoroute D2, due to a prohibition against using de-icing chemicals in order to maintain the quality of the water.

Direct winter maintenance operations consist of: road weather situation check-ups, salt spreading, snowplowing (snow removal), snow cutting, and simultaneous spreading and snowplowing. This is the reason for motorway administrator to prepare as best as possible for unpredictable winter conditions.

In respect to winter maintenance, each SSUD design takes into account the length of 50 - 60 km. The spreader vehicle which leaves SSUD (located in the middle) should get to the end and come back and managed with a normal load of ordinary use of salt per 1 square meter. The length is selected so that the drive would not take more than 2 hours.

Winter maintenance is carried out according to SSUD Winter Maintenance Plan. Organizational structure guarantees that personnel have non-stop service and workers (including the controller) take turns in regular shifts. Some workers are on standby duty. The controller (shift supervisor) submits information on roads serviceability to a workstation appointed by Ministry of Transport in set intervals or in necessary situations. The controller cooperates with the Police or other bodies of Road and Motorway Directorate, Integrated Rescue System, provide operation information.

RSD regularly monitor and assess the course of winter maintenance. At the end of the winter season RSD produce evaluation of technical and economical data with comments.

3.3 Assessment of the snow and ice control measures

Basic information concerning winter maintenance in 1999 - 2008 is shown in the table 2. It is especially the total salt consumption, average salt consumption per 1 km of motorway, number of kilometers driven at motorway check-ups, number of kilometers driven at winter maintenance operations.

The winter maintenance costs are above all the costs for salt purchase and operation of individual SSUD.

If the winter conditions cause exceptional number of maintenance operations the financial consequences will reflect to summer maintenance.

Winter maintenance is a specific section, because costs strongly depend on weather influence, which can only hardly be predicted when costs plan is being prepared. It is therefore difficult to predict total amount of costs concerning winter maintenance. However, on the other hand, winter maintenance cannot be restricted because of its importance, because insensitive economizing has an immediate impact on traffic ability of motorways and expressways.

Dependence of winter maintenance costs on weather conditions does not mean that winter maintenance could not be economically effective.

Deicing salt is purchased in a tender. When the preliminary conditions are fulfilled the cost decides. Costs are determined individually for every SSUD and quarter and they include all customs fees and transport. Costs therefore vary for every SSUD and quarter of the year in which salt is purchased. In second and third quarter they are 10% lower than in first and fourth quarter. Therefore, it seems that to purchase salt in summer season is the simplest form of economization. However, limited capacities of warehouses and possibility of unnecessary purchase of supplies which need not used in case of mild winter are factors against this strategy.

Possibility of basic procurement in advance in summer season is used, with the possibility of operative procurement of salt in winter. Contracts concerning

seasons	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08
consumption salt-t.	18,139	14,076	18,921	17,614	28,339	27,005	34,840	14,472	18,829
tonnes/km	35.6	27.2	34.7	32.3	50.2	46.0	58.0	20.6	26.0
km-check-ups	182,038	131,776	171,531	157,483	166,720	155,042	152,202	83,329	126,503
km-winter operations	327,160	250,770	362,658	276,191	489,984	436,911	583,617	239,283	333,888

TABLE 2 – WINTER MAINTENANCE DATA IN 1999 - 2008

supplies are drawn up in a way that the organization can purchase only such amount which corresponds to real needs and financial situation.

Precise dosage of salt has an important influence on its consumption. It is important to use mechanisms which reliably dose stated amount. It is not only because of economic aspect, but traffic safety as well.

Costs amount for winter maintenance is almost independent on any planning. Because these funds are drawn from the total plan, in case of harsh winters there is shortage of funds for summer maintenance. Therefore planning costs according to the harshest winter seems to be the simplest way. If however funds will be allocated based on some level of maintenance, relative waste of funds could occur. In this case it is ideal to actualize plan after first quarter with regard to past winter. According to long-term planning the optimal amount of financial funds is about 50 millions Czech crowns per year.

3.4 TRAFFIC SAFETY AND INFORMATION

The maintenance itself is above all based on:

a) permanent monitoring of weather conditions and potential development in particular road sections;

b) collecting information from users, the Police, other administrators, etc.;

c) monitoring meteorological stations and sensors data;

d) advice from the specialized Meteo work stations.

The basic impulse for immediate beginning of operations (spreading, plowing, etc.) is precipitation and its intensity. The precipitation may occur in form of rainfall, snowfall, combined, frost formation or glaze ice. Very important is the moment of the beginning of operations, or if possible their start in advance. This is very often based on a supervisor's experience.

The intervention circumstances, levels and situations can be determined by technical (technological) regulations with difficulties.

The intervention levels are set according to public and maintenance personnel general opinion on road surface quality which is not considered to be safe. For winter maintenance, the most difficult are those situations when the change in road serviceability is not apparent (frost, ice) and in addition they occur locally and very fast.

In the table 3 the problems and ultimate situations for interventions to eliminate them are shown.

Table 3 – Problems and solutions

Problem	Affects	Intervention situation	Return condition
Snow, snowing, snowdrifts	traffic flow consistency and safety	beginning of the situation	original conditions
Frost, ice	traffic flow consistency and safety	prevention, if possible	beginning of the situation
original conditions	Drizzling, rain	traffic flow consistency and safety beginning of the situation	original conditions

Recently, more and more often ecological and technological requirements are applied. Some of the ecological requirements are ground water protection, vegetation at the sides of roads protection, quality of the soil preservation. To guarantee appropriate winter maintenance quality it is necessary to harmonize a number of administrative, social, organizational, distribution and repair operations. It is necessary to consider climatic and geographical standpoints and use experiences from previous seasons. The administrator is always criticized for insufficient emergency service, late operations and also the fact he could use different methods and prevent damage and injuries.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

Representatives of the Czech Republic took part on solving of European research projects like:

- COST 343: Reduction in Road Closures by Improved Pavement Maintenance Procedures.
- COST 353: Winter Service Strategies for Increased European Road Safety etc. This way the transfer of the latest knowledge and new technologies concerning the winter maintenance is secured.

4.1 DISPATCHING MODULE OF WINTER MAINTENANCE OF COMMUNICATIONS

This principle of this system is to maximally simplify relevant information concerning probable weather development and pavement condition for the operator.

CZECH REPUBLIC

The information is targeted at the area of the operator's responsibility, i.e., it is relevant for a definite area of the road network. Data from road meteorological stations and other sources used up to present are still available and the possibility of detailed analysis and information evaluation is thus maintained.

This new solution moves from a detailed analysis of meteorological data to providing synthesized and clear information in a graphic form about supposed behavior of a road network in next few (about six) hours time frame. Thus is assured that an employee with a lower level of qualification or experience can use this software module without negative impacts on the winter maintenance quality.

The aim of the system is to correctly predict future conditions of the pavement based on predicted meteorological conditions, but not to determine the way and intensity of winter maintenance works.

Pardubice region was the first testing area of this system.

FIGURE 3 – MODULE OUTPUT

Inputs of this system are:

- meteorological data (CHMI, road meteorological stations);
- thermal mapping;
- knowledge and experience based information;
- geographic data;
- technical data of pavements;
- data about maintenance works.

Outputs of this system are:

- road surface thermal map;
- road surface condition map.

An example of the graphical output from the system is presented at figure 3.

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www.rsd.cz

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1 DEMOGRAPHICS & ROADS

1.1 INFORMATION ABOUT COUNTRY

Denmark consists of the peninsula of Jutland and c. 406 islands, of which c. 78 are inhabited. Of these, the largest and most densely populated are Zealand on which the capital Copenhagen is situated, Funen and the north Jutland Island.

Denmark has approximately 5.7 million inhabitants - this roughly amounts to 0.5% of the total EU population. In addition to Denmark itself, the kingdom also includes the Faroe Islands and Greenland.

Towards the end of the 19th century the main network of highroads was established as cobbled roads, which are roads with cobble (stone) material. Together with the secondary roads, the Danish road network had a high density compared with the rest of contemporary Europe.

Particularly during the 1960s and 1970s the network was further consolidated. It was drained and asphalted, supplemented with motorways and new main roads as well as many new local roads to keep pace with demand in the expanding urban areas.

In 2017 Denmark has app. 74,700 km of road, 1,229 km being motorways. With 1.68 km of public roadways per square kilometre, Denmark, then, has a road density that is among the highest in the world, with a general excess capacity.

1.2 ROAD NETWORK & TRAFFIC

The road network incorporates trunk roads (main national roads) and Local Council roads as defined by the road act.

Local Council roads are administrated by the local councils and constitute app. 70,650 km, about 95% of the public road network. National roads are administrated by the Danish Road Directorate and constitute app. 3,800 km; the remaining 5% of the public road network, still the public roads cover 46% of all traffic in km travelled vehicles. That means that 46% of all traffic in Denmark travels every day on 5% (3,800 km) of national roads.

The Great Belt Bridge, the Øresund Bridge and Øresund motorway are administrated by Sound and Belt Holding A/S and constitute 41 km in total.

The individual roads are classified according to their function.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The Danish climate is determined by the country's position on the edge of the continent of Europe close to large sea areas and in the zone of prevailing westerlies. This position results in cool summers with a mean temperature of around 16.4 °C and winters that are not particularly cold, with mean temperatures of around 1.9 °C. Denmark is thus placed in the temperate climate zone.

There is a good deal of wind, strongest in the winter and weakest in the summer. Precipitation falls throughout the year, with the greatest rainfall in September, October and November. The smallest amounts of precipitation occur in February and April. The regular distribution of precipitation throughout the year is due to Denmark's position in the belt of prevailing westerlies, where the predominant wind directions are west and southwest.

Series of low pressure systems (cyclones) moving north eastwards, often forming over Newfoundland, are the basis of the characteristically changeable weather: within a few days the weather changes typically from steady precipitation preceding a warm front to brighter or slightly misty weather, possibly still with a little drizzle in the following warmer mass of air. Finally, the passage of the cold front will produce precipitation in the form of heavy showers followed by clear weather with few clouds.

Denmark is one of the most exposed countries as regards „slippery road", because of the fact that of the temperature fluctuations around 0 °C during a winter. Until now preventative salting has been the solution to avoid slippery road, which means spreading by salt on roads will occur before it gets slippery. This outcome can be ensured with the help from the Road Weather Information System, today a technology used by Road Directorate and most municipalities to decide whether they start salting or not.

The average temperatures for winters are normally 0.5 °C. Number of complete days below 0.0 is around 20 days in a year. The variation of snow amount during a winter season is between 10-40 cm, and nation-wide snow weather occurs max. 20 times during a winter.

2.2 Salt index

The Danish Road Directorate uses a definite salt index to define the severity of a winter related to winter maintenance.

Formula of salt index:

$$Vi = \sum_{1\,oktober}^{1\,maj} V_{dag}$$

Vday = a • (10b + 0,1c + 7f + 18g) + 0,3a

a: Days with road temperature below +0.5 °C

b: is the number of times the road temperature is below 0 °C while the road temperature is below the dew-point temperature for a minimum period of 3 hours and with an interval of at least 12 hours.

c: the parameter c denotes the number of times the road temperature drops below

0 °C of at least +0.5 °C to -0.5 °C

f: If within a day measured precipitation below the freezing point in a total time of minimum: 30 minutes, f = 1 90 min, f = 3 270 min, f = 9 420 min, f = 12

g: When the road temperature gets below the freezing point examined whether there has been precipitation over the past 3 hours. If at least 3 logs have shown precipitation at the interval set g = 1

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS & RULES

In agreement with „law about winter maintenance and clearing of roads" the Danish road authorities are obligated to: take action for snow clearing and winter maintenance against slippery road at the public roads and paths.

For footpaths, the responsibility can be placed on the holder of neighbouring properties.

The road authorities determine to what extent and to what sequence snow clearing and winter maintenance against slippery road shall be made. Guidelines for workers performance is appointed as directed by the police.

Service objectives for Road Class	Type of road
State roads Freeways European Freeways	Priority roads Regional Roads Other priority roads
Other state roads	Other regional r oads

3.2 ORGANISATION AND OPERATION OF WINTER MAINTENANCE

Clear roads without any substance of weather condition.

The Danish Road authorities planning of winter services of own roads. The country is divided in 3 service centres equipped with 1 winter surveillance centre.

The winter central is responsible to act for entire national roads. All convenient jobs (haulage by truck o.l.) are supplied in accordance with EU's service- directive, and are managed by private haulage contractor.

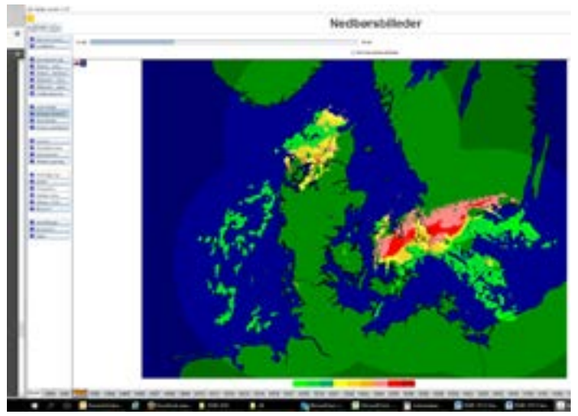
How to monitor roads?

It is not always easy to predict slippery roads when the weather conditions can change very quickly. Therefore, the department of winter service cooperates with a number of agencies and using advanced systems to assist in monitoring.

Winter service department cooperate particular with the Danish Meteorological Institute (DMI) and use their special forecasts for road and weather purposes, and radar and satellite imagery. Moreover, using the Road Weather Information System "VejVejr" (Road Weather), which provides comprehensive monitoring and forecasting facilities, so winter monitoring has the best possible basis for decision making in relation to the chance to call out for road salting.

Desired duration of Road Conditions:

	Call-out [Minutes]	Turnout duration Winter road class I (Hours)	Frequency Winter road class I (Hours)	Turnout duration Road winter class II (Hours)	Frequency Winter road class II (Hours)
Carriageways – salting	Max. 45	Max. 3-4		Max. 5-6	
Carriageways – snow clearing	Max. 90		2-5		4-8
Paths, sidewalks and other areas - salting/gritting	Max. 60 - 90	Max. 3-4		Max. 5-6	
Paths, sidewalks and other areas - snow clearing	Max. 90		4-8		6-10
Super Bike Paths - snow clearing	Max. 90		Max. 4		



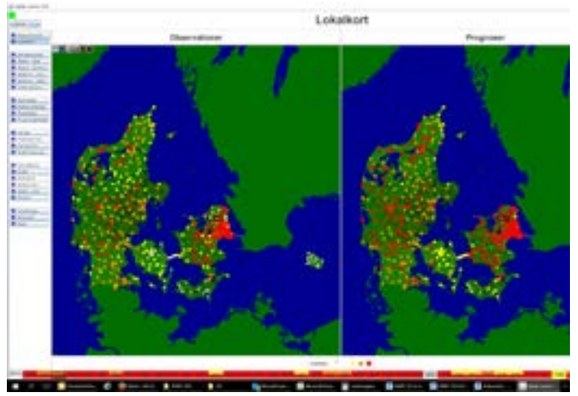
Information about road and weather situation by monitoring, webcams, police, citizen inquiries and winter monotoring is also used to form the total picture.

Winter supervisory is used when during Snow falls, where they are out driving on the road to examine the need for extra effort, for example in connection with the operation of formation.

Information dissemination

The general position within the Danish Road Weather Information System is shown below.

The Danish Road Directorate & Danish Meteorological Institute (DMI) have had an arrangement since 1983; the agreement is constructed to exchange information throughout Road Weather Information System and is mainly about road weather forecast and the objective is to maintain a satisfactory traffic ability and level of



traffic safety on the roads during a winter season.

Written agreements exist between every member that is connected to Road Weather Information System.

"Vejvejr" is a system that is installed in a series of computers including one national winter surveillance centre and 85 municipalities and other authorities. These receive and present data from the recording stations and the DMI (Danish Meteorological Institute).

These information's are communicated by the Road Directorate Traffic Information Centre, a central station in the Road Directorate which is open 24 hours a day and which maintains contact with road authorities, Danish Meteorological Institute (DMI), the police, the emergency services etc.

The information is also distributed via radio, e-mail, telefax, etc. and by direct telephone contact when motorists call.

The Road Weather Information System highlights icy driving situations before they actually arise, enabling preventive salting before it becomes icy. The stations are primarily located at the coldest places along the road network. The system has also affected the importance of control posts and patrols have less significance; however, patrolling is still used when necessary (snowfall etc.).

The Road Weather Information System is based on a network of approx. 470 recording stations. About 180 of them are placed on national roads and the rest on regional roads.

The winter crews' procedures to decide call outs for salting or snow removal are as based on:

- Online data about slippery road from monitoring stations located throughout the country
- Forecasts from each station - to develop the next 24 hours
- Residual salt measurements
- Freezing point temperature
- Regional weather
- Radar Pictures
- Patrol - monitor out on the roads
- Comments from motorists and police
- Experience - local conditions and vulnerable places.

There is 1 national winter surveillance central carrying out winter service around the country. The winter central have manned guards where winter preparedness is affiliated.

Traffic Information Centre

Traffic Information Centre (TIC) monitors the traffic situation throughout the year and forward messages to various media. Reports deal typically with traffic jams and accidents which cause problems for the flow of traffic.

In winter do TIC inform about warnings of slippery roads, and is an integrated part of the winter monitoring.

Methods

Winter service usually is provided from

1. Oct. - 30. Apr. throughout Denmark. Before that period, materials and equipment are checked and repaired and staffs are trained in comprehensive programmes.

Definite activation depends on the weather forecasts.

Establishment of technological procedures and experiments are normally planned and scheduled before winter seasons. The plan contains all instructions for personal and their duties. It also includes guidelines for the measurements that have to be done for a given climate situations.

Provision of snow fences has less significance in Denmark, mainly because of few snowy days, which counts to app. 20 days in a year and because of expenses related to small benefits.

Route optimisation happens individually for each route. The planning is made for entire road network based on requirements and occurs manually for all superior and subordinate road networks.

Founded on weather forecasts, if the snowfall appears or it has already taken place. The duty engineer must carefully decide when and in which extension snow clearing should be carried out.

Snow clearing of carriageway should begin, when the snowfall has reached to 3-5 cm. snow and there is prospect for continuous snowfall. Normally salting is a supplement to snow clearing.

However, these procedures are different from urban or rural area.

Snow clearing on paths normally happens during the clearing of carriageway but founded on practical knowledge, the paths should be clear after the adjoining road, otherwise the snow would just fall back again.

Equipment

Denmark has one operation winter surveillance centre. The operation centre is supplied with Danish Road Weather Information System and operating with the winter management system VINTERMAN.

The Road Directorate owns as for today 233 spreaders, and 581 snowploughs for securing against slippery roads, mostly pre-wetted salt-spreaders together with a couple of combination spreaders and liquid spreaders. The development in Denmark still goes to use of brine. Driving through of a salt route handles typical 3-4 hours from call-out to finished task, and route covers typical an area at brief 360.000 m^2.

Each spreader covers small 45-km. roads incl. stand-by spreader. Moreover, there is a salt depot for every 350-km. All new vehicles are supplied with stationary GPS equipment.

There is only a driver in the truck common for salting as well for snow clearing.

To start guiding of mentioned materials the equipment such as de-icer spraying installations, road he-

ating's and uses of ice-delaying pavements has been used but none of them are used anymore because of the results and the economic perspectives.

Manpower, training and privatisation

Every year there are seminars for engineers and road masters to inform about the latest knowledge and development within winter maintenance.

Training and education

The technical development of winter service demands education and in-service training of personnel.

For winter maintenance management and administrative staff exist, an in-service training arranged by Danish Road Directorate.

The classes included winter maintenance in practice and a depth examination of warning-system for slippery roads.

For drivers whom participant into the winter service, Road Directorate has in collaboration with the Transport Trade Education council has established a nationwide series of seminars for drivers in winter service. The courses are held at AMU (Adult Vocational Training) centres and/or suitable material sites. The courses are also approved for the compulsory training of drivers.

The courses are modular and contain topics such as basic winter service, winter road maintenance on roads and pathway, and snow removal. It is expected that participation to those classes will be demands for coming invitation to tender.

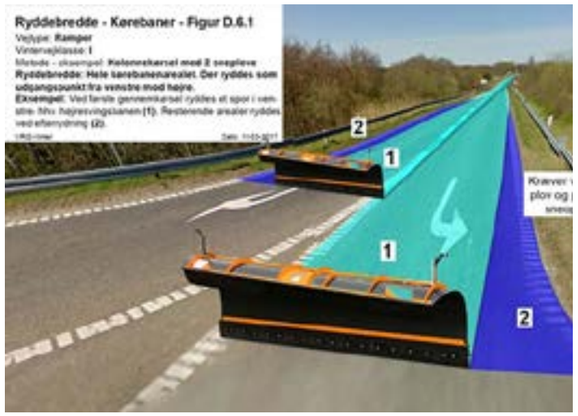
Privatisation

Private companies are usually hired to operate as drives in occasions of salting or snow clearing.

The government is contributing with equipment (spreaders and snowploughs) while private companies are supplying vehicles.

Operational organisation of winter maintenance

In a typical winter in Denmark, there are about 107 call-outs for salting due to risk of icy conditions, on approximately 4.000 km of the national and regional roads. Salting because of snowfall, on the other hand, occurs only 10-20 times a year. In Denmark, preventive actions are taken to salt the roads, before they get



slippery. The decision on whether a call-out is needed is made at a winter operation centres, while a local contractor carries out the actual activity. Two computer systems have been developed to support these tasks at the winter centre, the Road Weather Information System (RWIS) and VINTERMAN.

The decision whether there should be a call-out or not, is a very crucial decision. If many unnecessary callouts are made throughout a winter where icy conditions do not occur, money and resources are wasted.

On the other hand, if the call-out is made to late, or not at all, it can lead to accidents due to slippery roads and in worst cases a complete traffic jam. These situations also cost a lot of money for society. This means that each road authority tries to make the optimal decision in each case to ensure a stable traffic flow, but at the same time with a minimum use of resources. In order to reach this optimisation, the RWIS system is a big factor. If you can predict the timing and type for each slippery road condition, then it's possible to correspond in an appropriate way. This doesn't only include finding the optimal timing for the call-out, but also using the right methods and materials. In order to reach this goal, the VINTERMAN system was developed.

In this system one can create predefined action plans where the length of routes, methods and amount of salts etc. are decided. In addition, you have a choice between dry salt, pre-wetted salt, brine or a combination of both, depending on the weather situation.

Every salt spreaders are now equipped with GPS data collection. Information regarding speed, dosage, spreading width etc. is registered. Thus, VINTERMAN is able to provide statistics on the number of activities, consumption of salt, duration and time of callout along with the cost of salt and payments to contractors. This provides the opportunity to monitor and control the work quality, and eventually to re-organise action-plans if needed.

To increase the effect and optimisation of actions carried out, the Danish Road Directorate experiment with different types of salt spreading methods and materials. For example, the most recent research shows a big potential in salt reduction with usage of brine instead of pre-wetted salt in situations of rime (black ice).

3.3 ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

Internal assessment
Winter system

The Danish winter maintenance is mostly applied through EDB-systems and usually inside two main fields:

- Icy road warning. Especially if the needs are possibilities to carry out a preventive contribution, Road Weather Information System has to be established, based on the number of RWS, radar pictures and other meteorological information.
- Winter administration. The winter administration system is applicable as support connected with completion of prevention of icy road and thereby has to insure registration of activities, as necessary.

The systems can be integrated in a large familiar system; however, the interfaces between these two fields are so well-defined that it's often more suitable with smaller systems than a separate system.

Main tasks for a winter administration system, the winter maintenance is often organised differently from one road authority to another, but regardless how, a winter administration system is always required. The primary structures of organisation for completion of winter duty are:

A. Primary applications from own employees. In this case a winter administration system will secure options to document the contribution and estimate a resource allocation for the employees.

B. The own monitoring stations with decision round contribution, but with contractors to do the performance at the routes. In that situation the system will secure the data, so that the payment of the contractors proves in order.

C. All jobs are processed through an invitation to submit a tender, which includes decision about contribution as well as the contribution itself. In this case it will be with an asset to establish a corporate system that contractors as well as road authorities have facilities to. Typically the contractor has a need answering to model B, because the general contractor frequently employ subcontractor.

Information regarding all call-outs can later be obtained along with comprehensive data. Road centres are using these data in sending invoicing basis to the contractors. The organisations are frequently political to be certain; however to all three situations an administration and recording system of data is required around winter maintenance. The winter administration system must handle subsequent jobs:

Structure and organise all basics administrative information about winter maintenance.

- Assist to the callout situation and ensure that the required data of a contribution is registered.
- Give alternatives by subsequently documenting the performing contribution.
- Introduce statistical material regarding exported jobs, salt consumption and expenses.
- Handle report about present road condition, so the knowledge can constantly be shared out to the traffic information centres and various media.

External assessment

All performing spreaders at the Road Directorates roads are equipped with data-collecting equipment, which benefits the VINTERMAN system by viewing every single spreaders contribution. Subsequently this data can be employed as inspection of the contribution. On the other hand every driver completes a control scheme that documents contribution of any haulage.

In addition several road authorities checking, to this the amount of residual salt is known by measurement with SOBO20 and road sensors.

The Road Directorate make a national-wide user survey once a year and the users' opinion have an importance in the evaluation phase, in order to improve the strategy to obtain a satisfaction among the users.

3.4 TRAFFIC SAFETY & INFORMATION

With a high degree and accurately it is possible to inform motorists of icy roads and weather conditions both nation-wide and local.

This information are communicated by the Road Directorate's Traffic Information Centre, a central station in the Road Directorate which is open 24 hours a day and which maintains contact with road authorities, the Danish Meteorological Institute (DMI), the police, the emergency services etc.

The information is distributed by radio, telex, etc. and by direct telephone contact when road users calls or through websites www.vintertrafik.dk & www.trafikinfo.dk.

International exchange of road information

Supplement: International exchange of road information

The Danish Traffic Information Centre sends traffic information to ARC, from where it is distributed to many European countries together with traffic information from other countries.

The Danish Traffic Information Centre exchange traffic information across the border with Sweden in Datex II, and it is also the plan to exchange traffic information across the border with northern Germany.

In addition The Danish Traffic Information Centre sends traffic information to a number of international service providers. Supported by the EASYWAY VIKING EU-project exchange of traffic information across the border is being set up with Sweden, and it is also the plan to exchange traffic information across the border with northern Germany.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

The winter service technology improves very fast, and high-speed communication technologies and systems make it possible to transfer a large amount of data. With time, it also becomes less expensive. Already now it is possible to see very specific information regarding e.g. temperatures, winter service activities, road conditions and salt consumption, but there is still a lot that can be improved. All winter service vehicles equipped with GPS and data collection can be monitored in VINTERMAN.

Also as on-going project "De-Icers Management System DIMS" that has as main objective to calculate a proper dosage, based on parameters that have influence on slippery surfaces occur on roadways. The models behind it, should take the traffic intensity and precipitation, road temperature etc. in consideration. A further goal is to apply with dynamic spreading. Dynamic spreading, require that the system DIMS would be able to continuously computes new dosages as the salt spreader covers its route.

ROad STate MOnitoring System (ROSTMOS) is among projects that take place in cooperation with other Nordic countries and supported by the NordFoU organisation. NordFoU is a co-operation between the national Nordic road administrations to initialize, finance and run R&D projects. The project aims to develop a system for the registration/verification of road state that with high precision can monitor the condition of the road network in real-time.

The project will demonstrate how road state data can be collected and linked with other information such as weather conditions and operational measures in the form of snow clearing and gritting. It will also be shown how road state data can be used to improve the prognosis for the development in the driving conditions.

Test of salt spreaders in the Research centre Bygholm:

This project aims to examine whether a narrow the setting of spread width is important for slippery roads effectiveness, and whether there are differences in the use of combi- and pre-wetted salt-spreaders.

In order to identify the object, it is described in several objectives:

1. The salt transport on the road surface in relation to traffic speed, road conditions and time.
2. The importance of salt spreader speed
3. The importance of salt quality (fine-grained versus coarse-grained)
4. A determination of similarities / differences at use of the combi- and pre-wetted salt spreaders. The project team worked on the hypothesis that the salt spread in adjusted spreading width, will as a consequence of traffic impacts and road side fall slowly move to areas outside the adjusted spreading width. All the experiments show that the salt moves toward roadside and beyond the discount, but not all of the salt that makes it. Some of the salt by-fades completely from the road surface, which cannot be seen from the diagrams

Spreader monitoring and control:

Continuous development in changing road geometry needs much attention from the driver of the salt spreader, is a problem as drivers also need to watch the traffic and road profile.

The winter management system VINTERMAN in Denmark is under continuous development. In connection with this project they are now working with a system linked to GPS-guided salting tied to dynamic spreading where forecasts for weather and road conditions interacts to section based forecasts of road surface. The intention is that the driver just has to drive the lorry while the GPS and the program control the spreader.

The project includes examination with GPS controlled brine spreading with nozzles versus the spread of salt with dish.

Path Development Group:

Cycle tracks and similar, are currently subjected to attention in all Nordic countries. The goal is to, focus on the path spreader spreading quality and observations about road conditions and residual salt after salting.

Ice-carousel:

The purpose of Ice-carousel is both to determine friction energy created by the rolling resistance between tyres and the road surface and to determine traffic accelerating power and time of thawing of ice.

Traffic has an accelerating effect on the thawing of ice. The outcome may be utilizing to reduce salt consumption, or, at best cases, avoiding certain callouts for salting.

EPAS (External influences spray patterns - particular focus on salt quality, vehicle speed and drive system) is also a NordFoU project

The main goals in the project are to achieve knowledge about:

1. Correlation between driving speed and spray pattern by spreading prewetted salt with disc and spreading brine with nozzles and the effect off crosswind.
2. Correlation between salt quality and spreading pattern of pre-wetted salt with disc.
3. Correlation between the drive system and the spray pattern, pre-wetted salt with disc.

This project uses the knowledge gained through other projects regarding winter maintenance on roads, but combines it in a way that is usable for the operations level of the winter maintenance organisation.

5. REFERENCES

www.vd.dk
www.vintertrafik.dk
www.trafikken.dk
http://www.easyway-its.eu/

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Estonia is a small northern member-state of the European Union. Its territory can be compared to Denmark, Switzerland or Netherlands.

Area	45 339 km^2
Population	1 317 797
Density of population	29 per km^2
Capital: Tallinn	443 894 inhabitants
Latitude (capital)	590 44º N
Cars per 1,000 inhabitants	370
Density of national roads	366 km per 1,000 km^2

General facts about Estonia

Estonia is situated on the shores of the Baltic Sea with access to the Atlantic Ocean, extending its reach to the very centre of Europe.

Most harbours are located on the northern shore of the sea and, therefore, goods and people are used to being transported through Estonia. Nowadays international route Via Baltica (from Estonia through Baltic States) is developed.

The Republic of Estonia is administratively divided into 15 counties.

2 CLIMATE

2.1 STATISTICS ON TEMPERATURES AND PRECIPITATION

Snowfalls and slippery conditions usually begin in October and winter conditions last for 6 months until April. But we have had snow even in the end of May. The climate varies from the wet maritime on the coasts to the dry continental in the eastern and southern areas. We must be ready to meet quite low temperature like – 25 ºC. Road surface temperature often alters from minus to plus degrees and therefore the skid resistance control is utmost important.

1.2 Road network

Total road network km	National roads km					Other roads km
	Total, including :	Main roads	Basic roads	Secondary roads	Ramps	
58,936	16,594	1,609	2,405	12,478	102	42,342

Winter 2016/2017 in Estonia

Town	Monthly average Temperature (30-years average)					Snowfall (cm) (30-years max)		Precipitation (30-years average) (cm)				
	Nov	Dec	Jan	Feb	Mar	Daily maximum snowfall	Maximum snow depth	Nov	Dec	Jan	Feb	Mar
Tallinn	1.3	-1.9	-3.3	-4.3	-1.0	25	54	7.0	5.7	5.6	3.6	3.7
Tartu	0.3	-3.3	-4.6	-5.3	-1.0	16	42	5.3	4.9	4.8	3.5	3.8
Jõhvi	0.0	-3.6	-5.1	-6.0	-2,0	15	53	6.5	5.0	4.5	3.3	3.9

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Legal obligation to perform winter maintenance

Estonian Road Administration is responsible for the winter service of 100% of national roads in Estonia. Winter maintenance on all roads is regulated by following acts enacted by Ministry of Economic Affairs and Communications:

1. Requirements for the State of the Road.
2. Requirements for Winter Maintenance Technologies.

It is stated by the Traffic Law that winter tires are required to be used by vehicles up to 3.5 tonnes during the period from December 1 until March 1.

Driving with studded tires is allowed from October 1 to April 30.

Classification of the roads - Levels of service

ADT	Required level of service			
	Main road	Basic road	Secondary road	Local road
Motorway	4	-	-	-
over 6000	3	3	3	-
3001-6000	3	3	3	2
1001-3000	3	2	2	2
201-1000	3	2	1	1
up to 200	-	1	1	1

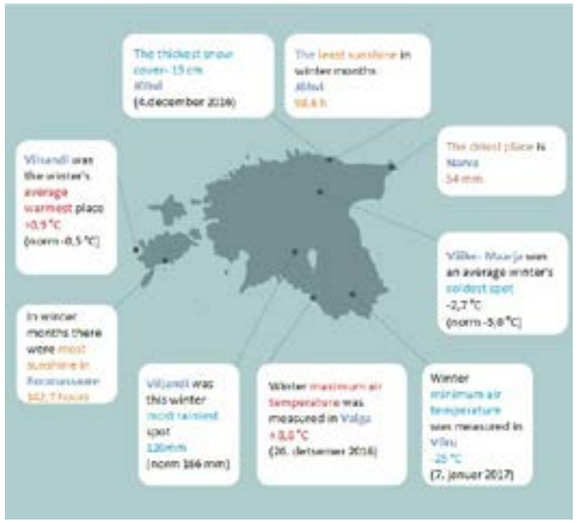
Indicators	Requirements for the state of road by service levels			
	1	2	3	4
State of road surface				
Allowed road condition	Packed snow or icy road surface is allowed with anti-skid treatment in unsafe spots.	Packed snow or icy road surface is allowed with entire anti-skid treatment	Sidewalk and all wheel tracks free of snow and ice de-icing	Sidewalk and road pavement is free of snow and ice entire de-icing
Required minimal friction coefficient	0,20 and at risk areas 0,25	0,25 on whole driveway	In wheel tracks 0,30 and in other driveway 0,28	0,30 on whole driveway
Snow critical thickness				
Allowed depth of loose snow	< 10 cm	< 8 cm	< 4 cm	< 3 cm
Allowed depth of slush, mix of salt and snow	< 5 cm	< 4 cm	< 2 cm	< 2 cm
Width between snow mounds	> 6 m or at least road width	> 8 m or at least road width	Whole driveway and shoulders	Whole driveway and shoulders
Evenness				
Allowed depth of ruts or unevenness in packed snow	< 4 cm	< 3 cm	Packed snow layer ~2 cm between wheel tracks	Bare pavement. When T < -12 oC snow layer < 1 cm between wheel tracks

Requirements for the state of the road

Level 1

Level 2

Level 3



Maximum Service Cycle Time (h)

Required level of service	Snow and slush re -mo- val	De-i- cing, anti- skid treat- ment	Salt- snow mix re-mo- val	Side- walks cle- aning and skid control	Treat- ment of other road faci- lities
4	2	2	4	6	8
3	5	4	8	8	12
2	12	8	-	12	24
1	24	12 (spots)	-	12	36

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Organization of winter maintenance

The three principal spheres of work of a maintenance undertaker – routine service. periodic service and retain repairs are all included in a single contract that lasts for 5 years. The evaluation of and payment for routine service is fully performance-based. That means there is no counting of amount of work that has to be done; the attainment of the required service level is what counts.

In Estonia, we have 5-years maintenance contracts. As of 31.12.2016 we have 18 countywide performance-based contracts (400-1300 km). In public procurements usually, 5-8 bidders compete. Road maintenance market is progressively developing in Estonia, depending on the location of road construction companies- the most developed is Tallinn area. Tartu follows the next. There is less entrepreneurship on islands and in the Southern Estonia.

The main winter service works are:

- snow and slush prevention from the roads and side of roads with the front and side ploughs of service trucks, graders and tractors;
- cleaning intersections, turn-offs, acceleration and deceleration lanes, public vehicle stops, waiting platforms, road and pedestrian crossings, parking lots and motorbus turn-over sites of snow and slush;
- cleaning bridges, overpasses and tunnels of snow;
- cleaning road signs of snow;
- ice prevention by sprinkling chlorides, abrasive materials or their mixtures or chloride aqueous solutions with gritters;
- removing ruts and irregularities;
- mechanical coursing with the scarifier blades and tooth blades of service trucks and graders;
- mechanical snow and ice prevention at level crossings;
- maintenance of speed camera booths and speed displays;
- placing markers.

Signs with the name and telephone number of a Traffic Information Center are installed on the borders of contract areas to inform road users and to promote competition between neighbouring maintainers.

Changes in the contracts. Establishing the winter service level 3+

On 01.10.2016, the biggest state roads were given the winter service level 3+. The winter service level 3+ means that the maintenance cycle is 2 hours to ensure the required coefficient of friction of the road; other maintenance times and requirements are the same as with winter service level 3. The winter service level 3+ applies on all weekdays from 5am–11pm, with the required level on other times being 3.

The main difference between level 3+ and 3 are the shorter maintenance cycles: during daytime, 2 hours instead of 4, and during night-time, 4 hours instead of 8.

Consumption of de-icing materials

The amount of de-icing materials is constantly decreasing because of the fact that new spreaders and the pre-wetting technology have been taken into use and de-icing is carried out on time.

The amount of salt used depends on winter conditions, especially on how many times temperature varies between plus and minus degrees. In the last years in winter in average 30-36 thousand tonnes of NaCl was used.

Costs of winter maintenance activities

Special requirements for start up, maintenance and using of ice roads are fixed

Ice roads are established for vehicles to move over a frozen sea between the mainland and the islands or over a lake connecting different places in the mainland. When signs of the ice road starting to form appear, all vessel traffic will be stopped.

Ice roads are established and maintained by companies having such expertise. According to the contracts made with the companies, the establishing and maintenance of the ice roads is the responsibility of the companies which have to conduct experiments, establish traffic control, organise surveillance, communicate the conditions of the road, etc. The Road Administration will monitor the fulfilment of the obligations of the contract.

The following rules apply when using ice roads:

- ice roads are open for traffic only during daytime; the traffic will be closed if visibility is under 300 m;
- the recommended driving speed is 25 km/h or 40-70 km/h (with speeds of 25-40 km/h, the vehicle may cause resonance that can do damage to the ice);
- on the ice road, it is permitted to drive only in the designated areas, with minimum intervals of 2 minutes;
- the distance between vehicles have to be maintained at minimum of 250 m;
- overtaking and two way traffic on the same lane is prohibited;
- driving outside the marked ice road is prohibited;
- the seat belts need to be unfastened and the doors need to be easily openable;
- uneven areas need to be crossed as slowly as possible;
- stopping the vehicle, speeding, driving in blizzard, fog or night-time is prohibited.

Main characteristics of Estonian Road Weather Stations and Road Weather Forecasts

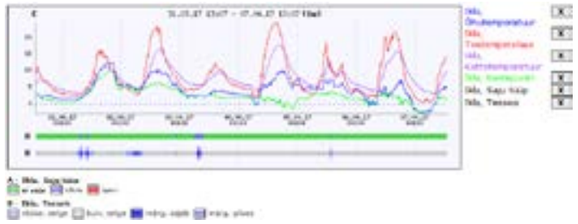
In Estonia four types of road weather stations are used: 31 ROSA, 5 RWS200 and 7 optical stations made by Vaisala (Finland) and 25 GMS stations made by Saab (Sweden). Finnish stations measure the same data as GMS stations plus valuable additional information about road surface condition, salt usage etc. ROSA/RWS200

stations measure the following parameters among others:

- air, dew point, surface and pavement temperature; air humidity;
- wind speed and direction;;
- type and amount of precipitation. also visibility (not in all stations)
- road surface status – dry, wet, snowy, slippery, icy etc.;
- the amount and concentration of salt.

Road weather stations do not provide any weather forecasts by themselves, they only give information about the past and present weather conditions on the road. Estonian Road Administration is buying/developing road weather prognosis data in good cooperation with Estonian Environment Agency and Finnish companies/agencies producing the data in question.

Another important part of Estonian RWIS are road cameras. There was 112 road cameras in Estonia at the beginning of year 2017 and this network is growing constantly; each year around 10-15 new cameras get

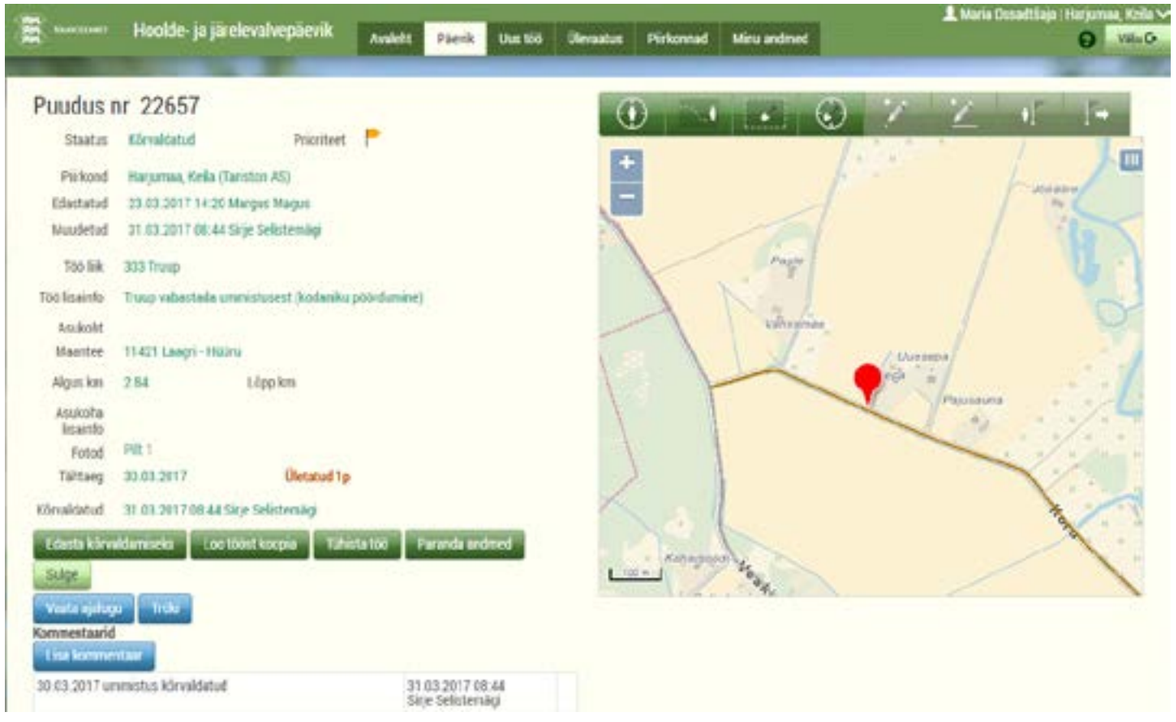


installed on state roads to give road masters visual information on road and weather conditions which is updated every 10 minutes.

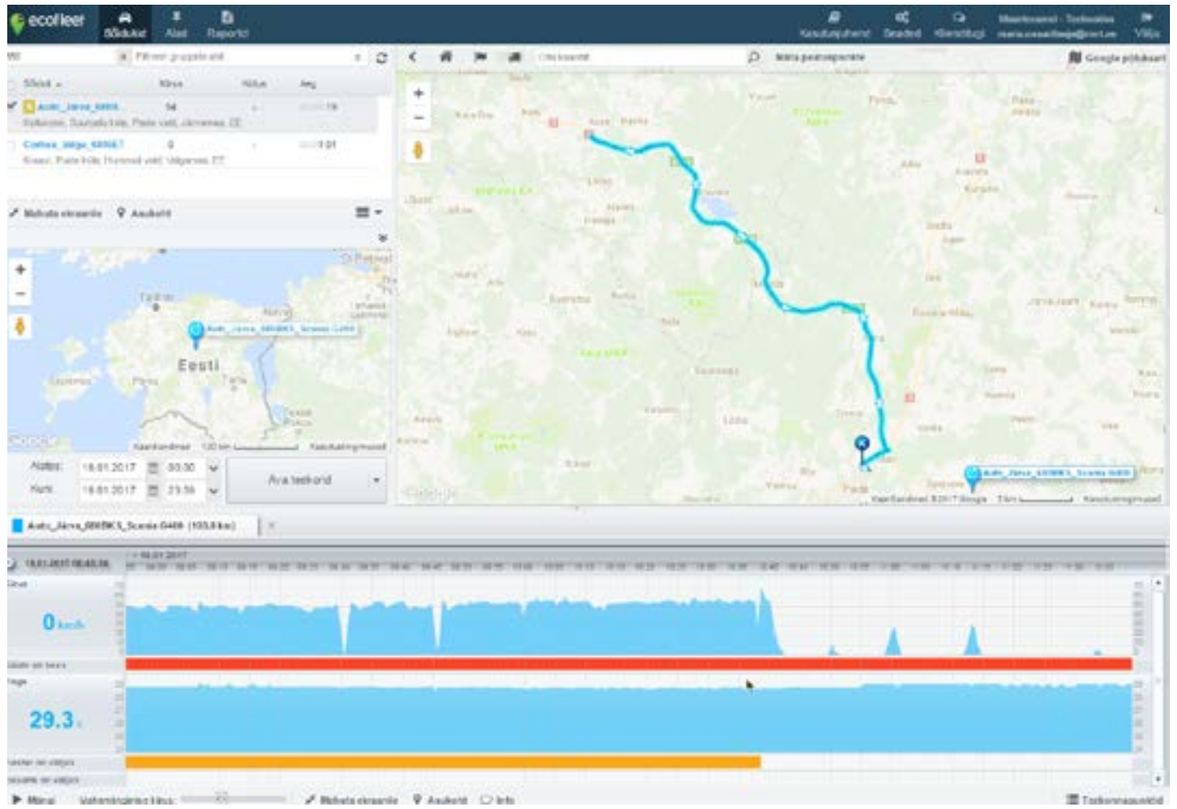
3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

The Guide for Inspection of Roads stipulates the road inspection order for supervision.

According to the Guide all inspections are grouped in two groups: one that is done on daily basis and; another that is done monthly.



A sample of a query from a new inspection logbook: (in Estonian)



GPS application of service vehicles: (In Estonian)

The main idea of daily inspection is to check selectively whether the actual road condition complies with the requirements stated by the Requirements for State of Road and whether operations of the maintainer are in accordance with the Technological Requirements for Road Maintenance Works. The route to be inspected is chosen according to the principle of importance by the supervisor doing the inspection. The purpose of monthly inspection is to check the actual road conditions in a wider area. The route to be inspected is chosen on the random basis. A commission comprising a representative of the contractor, representatives of the supervisors and owner do the inspection. During the monthly inspection 30% of roads at all service levels have to be checked.

Inspection is mainly done visually. In case of necessity different additional measurements can be done. Some of the measurable parameters are: thickness of snow, width between roadside snowdrifts, and depth of ruts, compliance with timeframes for maintenance cycles, etc.

Noticed shortcomings are written to the Web-based logbook and deadlines for correcting things are given. If the total amount of deficiencies is bigger than allowed, different sanctions against the contractor can be applied.

The development of the new surveillance diary started in the year 2014. From the beginning of 2016, new maintenance and surveillance diaries were enforced and the personnel of the maintenance works were specified and shown in the diaries. The next step in the development of the maintenance work diaries occurred at the end of 2016 when a section for making periodical overviews was added. Currently, there is a user-friendly information system in place for the surveying of road conditions which is of help to both the surveying spe-

cialists as well as to the drivers in assessing the inspections and work of the maintenance staff.

The surveillance staff of the Road Administration can via a specific app follow in real time the movement of maintenance vehicles.

In addition to the movement of vehicles, the work of snowploughs and gritters can also be observed.

3.1 TRAFFIC SAFETY AND INFORMATION INFORMATION PROVISION TO THE ROAD USER

Road Information Centre was established in 1997 to improve the traffic information for road users.

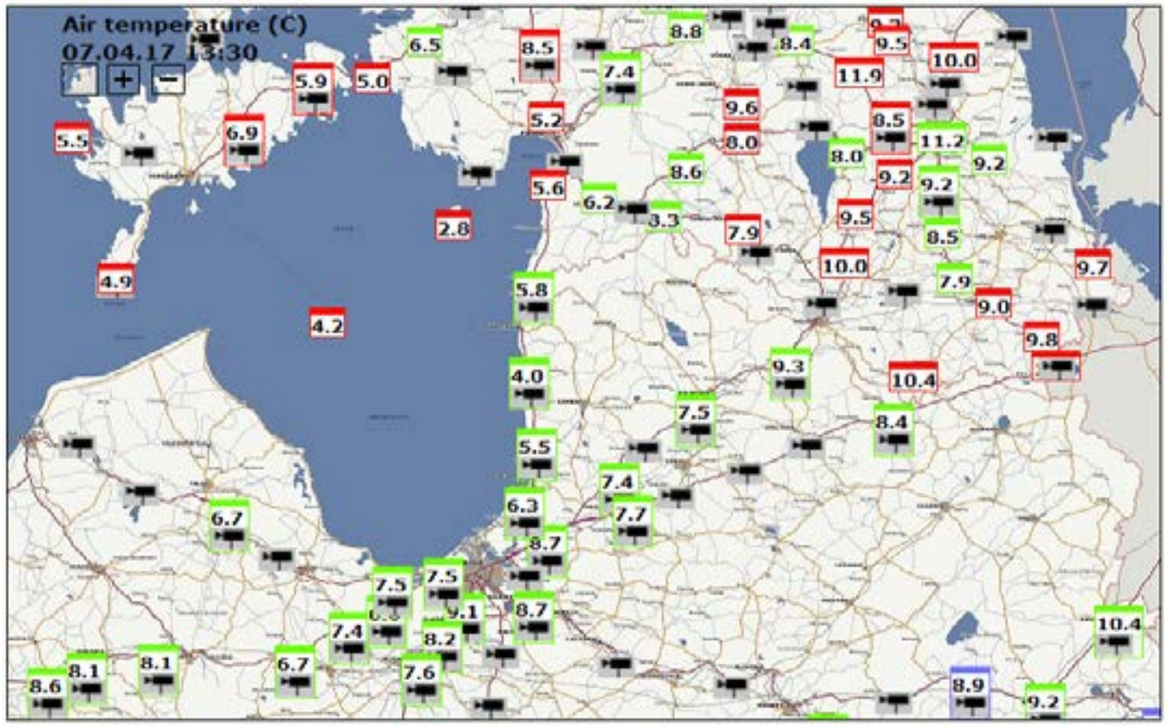
Estonian Road Administration was buying the service of collecting and spreading of road information from a private company. A 3-year contract was signed after an open tender held in the end of 2003. In the contract there were certain rules that the private company had to follow in collecting information from road weather stations, meteorological centre and road users.

In the September of 2011, Road Information Centre was added to the Estonian Road Administration, and it started servicing road users from the 1st of January, 2012.

The service was introduced to the Road Administration during the crisis of the snow storm "Monika" in 2010, when it was also decided to strengthen the crisis communication capabilities of the Road Administration. With the addition of Road Information Centre to the Road Administration, the modernisation and subsequent rapid development of the latter was made possible. In addition to the new work space in the Road Administration facilities, the Centre started a new traffic information system called Tark Tee ("Smart Road") in the summer of 2012. In the February of 2013, the Road Information Centre started providing phone service for the traffic registry. In 2014, the road information service incorporated the use of a GIS-based Road Information Centre's information system called MIKIS that provided new and faster options for receiving and managing information and notifying partners.

The Road Information Centre has to inform radio stations, police and road masters about traffic and road weather conditions at least twice a day and has to renew aforementioned information on Road Administration's web page as well.

So there are several possibilities for road users to gain information about traffic and road weather conditions: calling directly to the road information centre. looking at Road Administration's web page or www.balticroads.net web page.



A sample of a query from Web site

Balticroads.net – a cross border Road Information project

http://www.balticroads.net service is provided in cooperation between the National Road Administrations of Finland. Estonia. Latvia and Lithuania to inform road users of current road weather conditions in the Baltic Sea region.

Automated Road Weather Information System (RWIS) is used to continuously record the current and predicted status of driving conditions on the road network.

The four countries have joined resources to develop a common Internet interface to share and transfer the existing RWIS data collected around the Baltic Sea Region more effectively to the transport sector and other road users. The overall goal of the Internet interface is to provide better access to the accurate road weather information for the transport industry and the driving public thus resulting in better service and improved traffic safety. The co-operation between the national road administrations improves the utilization of the information from the existing road weather information stations in road maintenance operations.

The Baltic RWIS Internet interface provides current data (less than 30 minutes old) on the local road weather displaying data such as: road and air temperature; type of precipitation; road condition; wind speed and direction; as well as dew point and humidity.

Use of weather related road sensors and variable road signs

There is four variable message signs in Estonia, two of them are situated on Estonian-Latvian border, one on our main road Tallinn-Narva and one on Tallinn, our capital, border.

Suggestions about speed and warnings about slipperiness or other bad driving conditions are given to motorists via those signs plus some additional information - about general Estonian traffic rules for example - via border signs. Suggestions and warnings shown to motorists are mainly based on weather data gathered by nearby road weather stations.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

There are 2 different subjects related to winter maintenance that are researched at present.

The first is a friction factor of road pavements and possibilities of implementing its measuring system in Estonia to assess winter road conditions more precisely.

Second is about RWIS (Road Weather Information System) good quality road weather prognosis service. During winter 2016-2017 ERA (Estonian Road Administration) bought road weather prognosis data from Finland and made it available to all road maintenance companies for free. Our goal for next 4-5 winters is to develop this service locally in good cooperation with National Environment Agency.

5 REFERENCES

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DEMOGRAPHICS AND ROADS

1.1. Information about the country

Figure 1 Finland's location

Finland is a country in northern Europe with an area of 338,432 km2. It is situated between Sweden, Russia and Norway and borders on the Baltic Sea too. The country has 5.5 million inhabitants, 16,25 per square kilometer, most of whom (71%) live in towns or urban areas. The average percentage in EU is 73%. About one million people live in the metropolitan area of Helsinki.

1.2. Road network and traffic

Roads are especially significant in Finland, because it has a large surface area but is sparsely populated. What's more, from the viewpoint of central Europe, Finland is located on the margins. Most exports to this most important market area are transported by sea. From the standpoint of the competitiveness of industry and commerce, functional logistics are vital, especially the functionality of the internal transportation system. Road transport accounts for 67% of total freight transport.

The road network comprises 78,000 km of public roads, of which 50,745 km has asphalt pavement. 890 km of these are motorways. In addition, there are 30,000 km of streets and planning roads and 350,000 km of private roads.

Kilometrage on state roads is 38 000 million km and the share of buses and trucks is 3,300 million km per year. Public roads carry about 79% of all traffic.

Traffic volume during the six winter months is around 45% of the year-round volume. In many fields of industry and commerce, the share of transports taking place in the winter months is greater than that in summer. Communities, industry and commerce that depend on transports and road traffic expect transportation to function reliably all year round.

Area	Total snowy regions	338,432 km2
Population	Total snowy regions	5.5 million
Length of road	Public state roads	78,000 km
	Streets and planning roads	26,000 km
	Private roads	350,000 km
Latitude (capital Helsinki)		60°19'N

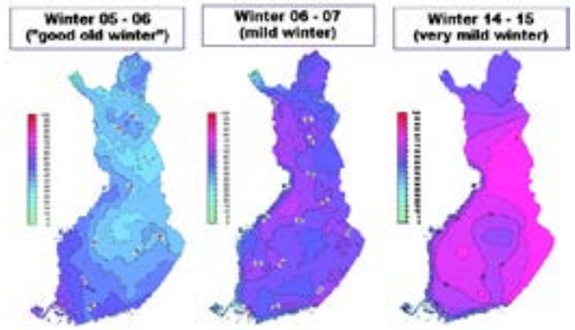


Figure 2 Effects of climate change on freeze-thaw cycles. (Temperature under 0 °C times/winter)

CLIMATE

1.3. Overview of climatic areas

Finland is situated between the 60th and 70th northern parallels in the Eurasian continent's coastal zone. The mean temperature in Finland is several degrees higher than that of other areas in these latitudes, e.g., Siberia and south Greenland. The temperature is raised by the Baltic Sea, inland waters and, above all, by airflows from the Atlantic, warmed by the Gulf Stream.

Conditions differ in the various different parts of the country. In the coastal areas, where the climate is closer to a marine climate, weather and driving conditions vary greatly and slippery conditions develop easily. In the country's eastern and northern parts, the weather resembles a continental climate and is clearly colder. However, winter maintenance is getting more challenging in eastern and northern Finland also because of climate change (Figure 2).

1.4. Statistics on temperature and precipitation

In Southern Finland the average winter temperature is about -2 °C and in the North approximately -7 °C (Figure 3). However, the average temperature in recent years has been about 0 °C in Southern Finland and abo-

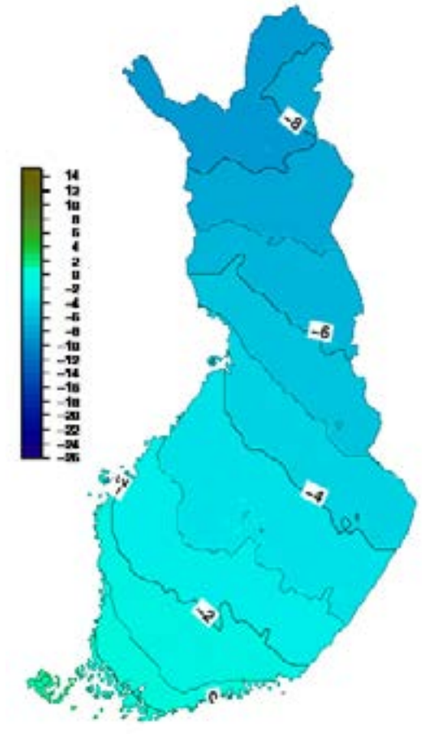


Figure 3 Mean annual winter temperature (°C) during 1981-2010

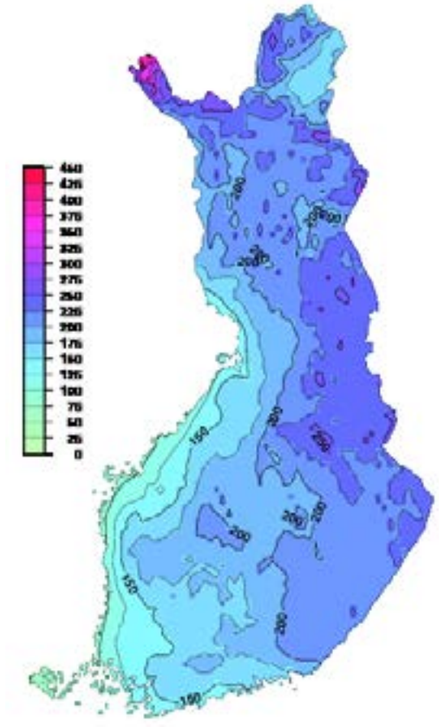


Figure 4 Mean annual snowfall (mm) during 1981-2010

ut -5 °C in the North. The annual rainfall is less than 600 mm in the North and 600-700 mm in the South.

Permanent snow falls usually in October or November in the North and in December in the South. The long-term average snowfall converted to millimeters of water varies from 75 to 250 mm in different parts of Finland (Figure 4). This amount of snow accumulates throughout the winter season, mainly as snowfalls under 10 mm.

There is a costal climate on southern and western part of Finland and more a continental climate in eastern and northern part of Finland. The Baltic Sea and especially the Gulf Stream are making the climate warmer. Weather conditions can change quickly in wintertime.

The anti-icing is main concern in coastal area and snow removal more in eastern and northern part of Finland due to the climate differences.

1.5. WINTER INDEXES

Finland does not currently use any index that would describe the severity of winter purely from the perspective of weather conditions.

Finnish Transport Agency procures road maintenance, and the leveling out of the pricing risk resulting from the level of severity of the winter must still be taken care of between the client and the contractor.

2. WINTER ROAD MANAGEMENT

2.1. STANDARDS AND RULES

The Finnish Transport Agency is a state agency responsible for the management of the countrywide public road network. Streets in cities and municipalities are the responsibility of the municipalities. The private road network is the responsibility of the landowners living along the private roads.

The winter maintenance policy is based on traffic laws concerning winter tires, especially studded tires, and on the possibility of using salt to combat slipperiness. Winter tires have to be used from 1 December to the end of February. Studded tires are allowed to be used from 1 November to 31 March.

Road classification

The road network is divided into six main maintenance classes (Ise, Is, I, Ib, II, III). In addition, class Ib has a corresponding maintenance class TIb for built-up areas. Pedestrian and bicycle paths are divided into two maintenance classes (K1, K2).

Each class has a different level of service and quality standards. The level of service is mainly defined according to traffic volume, road functional class and regional climate, but local conditions, nature and composition of traffic, speed limit and qualitative integration with the level of service of municipality's road network are also taken into consideration.

Most of the main road network belongs to categories Ise, Is, I and Ib. Categories Ise, Is and I are completely free of ice and snow for most of the winter. Salting is the main anti-slipping procedure on these roads. Class Ib is maintained using less salt and the conditions are clearly more wintry than in categories Ise, Is and I, but otherwise the level of maintenance is high. Classes II and III are used on roads with low traffic vlomes. Very little salt is used. Instead, sand or roughening the road surface are used to combat slipperiness.

Quality standards

A friction value is an important quality standard in Finland because packed snow and ice are also allowed on the main roads. The traffic volume on many road sections of the main roads is so low that a reasonable amount of salt is not able to keep them bare. The friction value is measured by friction meters (either traditional braking meters like El-trip or new acceleration sensor meters).

The following tables present the main quality standards and reaction times of winter maintenance.

Table 1 Correlation between friction values and driving conditions. The friction value is measured by C-Trip

Friction value	0.00-0.14	0.15-0.19	0.20-0.24	0.25-0.29	0.30-0.44	0.45-1.00
Road surface condition	bad driving conditions, wet ice, very slippery	icy, slippery	tightly packed snow, satisf. winter conditions	rough, packed ice and snow good winter conditions	bare and wet, not slippery	bare and dry, not slippery

Table 2 Quality standards of anti-icing

Winter maintenance class	Ise, Is	I	Ib	II	III	K1 K2
Normal Friction requirement	0.30	0.28	0.25			
	road surface below -6 °C 0.25	road surface below -4 °C 0.25	spot sanding 0.25 line treatment 0.22	Roughened surface, problem locations are spot sanded	Roughened surface, problem locations are spot sanded	According to traffic needs
			Line sanding of icy compacted snow	Line sanding of icy compacted snow		
Cycle time	Ise: 0 h, Is: 2 h	2 h	salt 3 h, sand 4 h	6 h line sanding	8 h line sanding	2 h

Table 3 Quality standards for snow removal

Winter maintenance class	Ise, Is	I	Ib	II	III	K1	K2
Maximum snow depth	4 cm	4 cm	4 cm	8 cm	10 cm	3 cm	4 cm
Cycle time	2.5 h (slush 2 h)	3 h (slush 2.5 h)	3 h	4 h	6 h	3 h	4 h
						Ploughed clean before 06	Ploughed clean before 07

Only half as much slush is allowed as snow.

Table 4 Quality standards for surface evenness

Winter maintenance class	Ise, Is	I	Ib	II	III	K1 K2
Evenness requirement	-	1 cm	1.5 cm (TIb 2 cm)	2 cm	2 cm	2 cm hindering ruts

Tailor-made maintenance

If special traffic needs so require, timing or quality on specific sections on road may be modified locally without changing the maintenance class. The target of tailor-made maintenance is to improve the service provided for road users based on the special needs of the customers.

Rules regarding materials and equipment

Winter maintenance is ordered from contractors based on the principle of quality responsibility. It is mostly the contractor's own decision as to which kind of maintenance actions and equipment are used. However, tractor usage is not allowed on main roads. The equipment has to meet also certain standard requirements like minimum Euro III for trucks and stage II for tractors. The equipment has also to be safe, noticeable enough and suitable for the use.

The anti-icing materials has to meet client's requirements. Only moistened salt and brine are allowed to be used to prevent slipperiness. Calcium chloride is not recommended but allowed to be used in small amounts for moistening or to prevent black ice. Also potassium formate is used locally in aquifer areas because it has proven to degrade before it goes to ground water and does not cause more corrosion than sodium chlorite. The size of the de-icing sand grains must be 6-8 mm depending on the road class.

The customer satisfaction bonus

The Finnish Transport Agency has actively tried to find ways to improve the service provided for road users. The target has been to find ways of improving the service without significantly increasing the costs. As one of the ways of encouraging contractors to serve road users better, the Finnish Transport Agency has de-

veloped a customer satisfaction bonus to be paid to contractors if satisfaction is high enough.

In spring 2004, a separate research and development project was done to develop the customer satisfaction bonus, as well as already piloting the bonus scheme at the same time in relation to five contracts that begin in 2004.

The bonus, which is based on customer satisfaction, has been used since 2004 in little different forms. Bonus on customer satisfaction is available annually. The extent of the bonus depends on 6 different assessment factors, of which 4 relate to customer satisfaction, one deals with the success of winter maintenance and one relates to the success of summer maintenance on the basis of an assessment carried out by the client. The assessment carried out by the client is based on the reporting of the contractor in relation to measures taken. Customer satisfaction bonus is paid annually and the extent of the bonus varies between 0 and 2 percent of the annual costs of the contract.

The bonus system has not proved to be as good as expected. Customer satisfaction is so strongly depending on weather conditions that it effects more than the contractor's actions. The bonus system is, however, an effective way to get contractors to understand that road users are also their customers.

2.2. ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Organization

In 2001 the Finnish National Road Administration was divided into the Finnish Road Administration (Finnra), which orders services from producers, and the Finnish Road Enterprise, which takes care of construction and maintenance among other contractors and also provides consultation services. In the beginning of 2008 Finnish Road Enterprise became known as Destia. The Finnish Road Administration, Railway Administration and Maritime Administration were united together and the Finnish Transport Agency was established in the beginning of 2010. The regional Centres for Economic Development, Transport and the Environment (ELY-centres) manage the regional implementation and development tasks of the state administration.

The Finnish Transport Agency specifies national policy, quality standards and guidelines of procurement process. The regional ELY-centres are clients doing the competitive biddings in practice and paying to contractors.

In Finland, client orders winter maintenance along with summer maintenance as area maintenance contracts from contractors. The contractors for each regions are chosen on price. Some standards for quality and company turnover has to be met also. A new contract model based on target price is also piloted since 2014.

There are four ELY-centres, which are responsible for the ordering of the maintenance to different parts of Finland under guidance of the Finnish Transport Agency. The total amount of ELY-centres responsible for traffic is nine. There are 79 regional contracts and a long-term life-cycle contract on some road sections of E18. Every regional contract includes 450-2300 km of road network and lasts 5 years.

Determining the level of service of winter maintenance is the responsibility of the Finnish Transport Agency. Road users' opinions regarding the maintenance of the previous winter are sought out by a customer satisfaction survey every spring. They are taken into account in the planning work when possible. Direct feedback from the road users is also collected.

Operational management

Each contractor has the overall responsibility for the maintenance of the roads included in the contract area allocated to them, taking care of the supervision of the work, the performance of the maintenance duties, the assurance of quality and the necessary purchases.

The contractor plans and decides on the procedures that are to be carried out in relation to the road network and, by monitoring weather conditions and the conditions of the roads, ensures that the necessary measures are carried out at such a time that allows for the fulfillment of the quality requirements. In addition, the contractor is responsible for acquiring the equipment necessary for carrying out the work, as well as the personnel and materials. Most of the practical maintenance actions are nowadays carried out by subcontractors. The contractor must present a plan to the client regarding the execution of the procedures and quality assurance, prior to signing the contract.

The most important measures involved in the maintenance of roads in a condition set out in the quality requirements during winter are the removal of snow, prevention of slipperiness and ensuring a level surface of the road. In addition, the contractor must ensure that traffic signs are clean and that banks of snow are lowered. The contractor must also keep in contact with the contractors responsible for adjoining areas, in order to ensure consistency in quality across the borders of different contract areas.

Road information provision

In order to ensure the timeliness of winter maintenance, various kinds of information on the current and impending weather conditions are necessary. To this end, client (the Finnish Transport Agency and ELY-centres) has at its disposal road weather stations and weather camera systems. In addition, client subscribes to various kinds of weather reports as well as satellite and

Figure 5 Locations of the road weather stations.

Figure 6 Locations of the weather cameras.

radar images from external organizations. The supplier of weather information is also selected through competitive tendering. The weather information produced and subscribed by client is also available to the regional contractors. Contractors can acquire additional weather information services to those provided by the client at their own expense.

The road weather station network consists of over 375 road weather stations. The stations gather information on factors affecting the weather and driving conditions, such as the temperature of ambient air and the road surface, wind velocity and the moisture level of the road surface. The road surface information is assessed using a small sensor placed on the road surface. In addition there are optical remote surface state sensors, which give also the surface friction value (0.0-1.0). These sensors are combined to the 150 normal road weather stations. In the winter, road weather information

is updated at least three times an hour. The information is updated more regularly when the temperature approaches zero, as this is when the weather is at its worst from the perspective of drivers and road maintenance staff. The locations of the road weather stations along the road network are shown in Figure 5.

The weather camera network of the Finnish Transport Agency and ELY-centres comprises over 500 weather cameras. The network provides equal coverage of the whole of the Finnish public road network. In the autumn and the winter, all cameras are operational. The weather camera image is updated at an interval of approximately 15-90 minutes; more regularly in bad weather, and less regularly in good weather. The locations of the weather cameras along the road network are shown in Figure 6.

2.3. ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

Costs

The modest average daily traffic and long road network, which is maintained year-round to ensure usability, unavoidably leads to a relatively low level of cost-effectiveness. The annual winter maintenance costs have, however, been in same level as a result of competitive bidding. Winter maintenance costs of state roads (78,000 km) are about 99 million euros. This indicates a cost of approximately 1,270 euro/km. In addition to this, some costs come also from road weather system maintenance and information systems.

The Finnish Transport Agency finds the winter maintenance of lower-level roads (usually with a maintenance class of III) an especially demanding challenge and the users of these roads are unsatisfied with the maintenance. The length of lower-level roads is considerably higher than that of main roads, but percentage of kilometers driven on these roads is very low. The average daily traffic is often only a few hundred vehicles a day, whereas ADT on main roads usually is some thousands and tens of thousands near biggest cities. This is why focus on the maintenance of main roads provides higher efficiency in improving safety in traffic, for example. Most fatal head-on accidents on winter time take place on main roads. Due to the large number of lower-level roads, even a small increase in the level of quality creates significant additional costs. The division of roads, traffic and winter maintenance costs in relation to different maintenance classes is shown in Figure 7.

Figure 7 Road lengths, percentage of trafficand costs of winter maintenance in different maintenance classes 2012.

Salt consumption

The most significant environmental issue resulting from winter maintenance is the damage suffered by ground water due to the salt used in anti-icing. The use of salt has traditionally been popular in the coastal regions of Southern and Western Finland, where weather conditions often change suddenly and traffic volume is high. However need of salt usage has increased inlands also because of climate change. In some areas of Northern Finland, there is no need to use salt at all, as the amount of traffic is low and the weather conditions are colder and more stable. Amount of salt use in winter maintenance has been quite stable per kilometer already for 20 years.

The reduction of the harmful effects of salt is aspired to in many ways. According to the winter maintenance policy of the Finnish Transport Agency, very little salt is used on groundwater areas for anti-icing, or potassium formate is used and probably natrium formate in future also.

Due to significant wastage, the use of dry salt is forbidden as anti-icing. Salt is applied either as a solution or it is moistened prior to spreading. Roads in classes Ise, Is and I are kept unfrozen throughout the winter, as a result of which slipperiness of these roads has been prevented in advance, whereby less salt is required than in situations involving already-formed layers of ice.

In order to restrict the use of salt, the Finnish Transport Agency also defines on an annual basis the amount of salt to be used in each contract area on the basis of salt amounts used in previous years and winter maintenance classes. In addition, separate, stricter restrictions are set for the use of salt on the groundwater areas. If the contractor uses more salt than has been agreed a year, fines will be enforced. Previously salt bonuses were also used to encourage contractors to minimize salting. The accepted amount of salt is, however, increased in winters that are considerably warmer than average.

The contractor is also expected to store the salt in covered facilities that have drainage, to ensure that groundwater across the rest of the environment is not at risk.

Assessment of the work

The contractor is responsible for ensuring and demonstrating the achievement of the quality of their work, as agreed in the quality plan. Quality reporting comprises reporting of the procedures that have been carried out and any deviations that have occurred. The reporting maintenance actions takes place on real-time on client's information system. Maintenance actions are also shown to road users in real-time through FTA's internet pages. . The contractor is expected to fill in a separate deviation report whenever the quality requirements are momentarily not met in relation to an individual section of the road network.

The client monitors the efficiency of the quality assurance measures taken by the contractor, and carries out random checks to ensure that the work is being carried as agreed. Consultants are used to assist these random checks, especially during night time and at weekends. If a failure to meet the quality requirements is identified, the contract will receive a warning or a fine.

Winter maintenance in contracts is based on total price. The contractor will receive payment for the work done on a monthly basis.

2.4. TRAFFIC SAFETY AND INFORMATION

Informing traffic of road conditions improves safety and smoothness of traffic and reduces damages and harm suffered by the road-users and the environment. The Finnish Transport Agency has a Road Traffic Information Center that provides road-users with up-to-date information on the traffic and weather conditions as well as disturbances in traffic, such as accidents.

The Traffic Information Center provides information on traffic conditions primarily through the mass media – the radio, television and the Internet. The images from nearly 460 weather cameras and over 100 traffic cameras of the Finnish Transport Agency as well as information gathered by about 400 road weather sites are available on the website of the Finnish Transport Agency. Road users can also report any disturbances that they witness on the roads to the line for road users maintained by the Traffic Information Center. In addition, road users are guided with the help of variable road signs and traffic symbols to select their route in such a way as to make travel time as short as possible and the level of service as high as possible throughout the journey.

Variable speed limits exist on some important main roads and motorways comprising over 400 kilometers in total. The speed limits are displayed according to the

road surface condition, weather monitored and traffic volume in real time. Occasional disturbances for traffic such as road accidents or road maintenance work may be reasons for a lowered speed limit displayed as well. Furthermore, variable message and traffic signs may be used as complementary tools, for example, to inform the drivers of road weather conditions or important traffic incidents. Variable speed limit signs have also been installed at some special sites where accident risk is high, in order to lower the speed limit for a short period of time.

In addition to the road weather stations and the weather cameras, the Traffic Information Center gathers the information it needs for communicating and guiding traffic through an automatic traffic measuring system (LAM). The system comprises 450 traffic-measuring devices with sensors placed on the road as well as the related systems for transferring, storing and printing out the information. The system provides information on the amount of traffic on a stretch of road, the average speeds and the overall time spent on a journey.

The information is used not only for monitoring and communicating traffic issues but also for planning road maintenance. For example, the daily maintenance of a road can be carried out in a more meaningful and economic way through taking advantage of the information on amounts of traffic at different times of the day. The system also provides information for traffic safety studies, indicating the breakdown of a driving experience in terms of speed and distance between cars in different conditions and as a result of different factors. By combining traffic information with the weather information produced by the road weather system, the development of accident risks can be studied with regard to different weather and congestion conditions, as can the effect of winter time speed limits to the average speed of cars, for example.

In addition, the Traffic Information Center receives up-to-date information on the condition of the road network from other authorities, such as the police, the emergency centers, road services and regional contractors, as well as from road users via the telephone line for road users. Special road weather forecasts are produced by meteorological services and weather radar and satellite pictures are available for both winter maintenance operators and the Traffic Information Center.

Winter time speed limits are used in approximately 9000 kilometers on average for five months a year. Lowered wintertime speed limits save 12 lives a year. The use of winter tires is mandatory from 1st December to 28th February. Accident risk during winter period is the same than summer period.

On-going Research and Studies to Improve Winter Management

Developing friction meters

In Finland, the road authorities, quality control consultants and the private winter maintenance contractors measure the road friction. The Finnish Transport Agency specifies the instruments and methods to be used in state roads friction measurements. In Finland, during last 25 years, road friction measurement has based on the method, where the small electrical in-car accessory determines the deceleration during braking and therefore estimate the friction.

These traditional friction meters have one remarkable shortage: the meter installation needs professional expertise and becomes more difficult when electrical systems in the new vehicles are getting more complicated. That's why new friction meters utilizing acceleration sensors are today so interesting. For these new meters, it's enough to install them firmly near to the dashboard. If the installation is firm enough, the deceleration measured by the acceleration sensor is same as the deceleration of the vehicle during braking. And the friction value displayed is relative to the deceleration.

The object of Finnish friction studies has been to assess if the new friction meters with the acceleration sensors are so reliable and accurate, that these meters can be utilized in winter maintenance quality control in Finland. Furthermore, the object has been to determine quality requirements for friction meters.

Friction meter comparison study included several friction meters intended to use in winter maintenance quality control, as well as some other types of friction meters.

As a result, the quality requirements for friction meters were introduced and many new meters based on acceleration sensors were accepted for friction measurements.

Finland has put a lot of effort on digitalization in government period 2015 19. For example digital procurement, fleet information, continuous photo-shooting and real-time information systems have been developed. Many experiments have been done with optical mobile friction measurement devices. Finland has also participated RostMos-project (Nordic Road state Monitoring system) since 2016. One of the projects aims is to compare different friction measurement devices and their accuracy in different road conditions.

New contract models have been piloted actively during last years in Finland. Program Managed Performance Based Maintenance Contract (PBMC) model started in Contact of Espoo year 2014. The contract model is more open than traditional area maintenance contract. The aim is to develop more simple and feasible version of this contract model and introduce it 2019 in those areas where the contacts will end year 2019.

New information and reporting system of maintenance HARJA was taken into production use October 2016. The HARJA system combines information from several of the client's databases as well as certain data from contractors' information systems. The total number of systems has now decreased, and monitoring is now easier to coordinate. The system is essentially based on contracts financial follow-up and reporting maintenance actions done. The material reports include, among others, the volumes of sand and salt used in the winter. The HARJA system can be used to monitor winter maintenance actions through a real-time map interface or to browse previously completed actions. Contractors and the client can upload weather reports and quality data into the HARJA system using a mobile interface directly from the roads. Road user feedback can now also be viewed on a map.

3. References

Statistics Finland: http://www.stat.fi/index_en
Finnish Transport Agency: http://www.fta.fi
ELY-centres: http://www.ely-keskus.fi/en
Travel and traffic information:
http://www.liikennevirasto.fi/alk/english/

FRANCE

1 DEMOGRAPHICS AND ROAD

1.1 INFORMATION ABOUT THE COUNTRY

Surface area	551,695 km2
Population	66.9 million
Density	117,6 per km2
Capital	Paris
Latitude (capital)	48,8 N

France is a medium-sized country on the Atlantic seaboard, with a population of 66.9 million distributed somewhat unevenly.

Its geography and climate are diverse, making France a preferred tourist destination. Aside from the major economic activity generated by tourism, France's industrial and agricultural sectors remain very active. Its administrative organization and history have endowed France with a dense road network.

1.2 Road network and traffic

The French road network represents about 1 million kilometers. Depending on the type of road, it is managed by the State, local authorities or concessionary companies:

State departments, divided into 11 DIRs (directions interdépartementales des routes - road directorates operating across several French départements)	National roads and non-concessionary motorways (12,900 km)
Département councils	Département roads 380,000 km
Towns	Communal roads (600,000 km)
Concessionary motorway companies	Toll motorways (9,000 km)

Private car transport accounts for the bulk of passenger transport (83%); similarly, goods are mainly transported by road (85%)

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC ZONES AND MAIN WINTER EVENTS TO BE CONTROLLED

France has 5 main areas:

- Mediterranean climate
  Temperatures are mild in winter (6 to 11°C on average in January), but sometimes fall suddenly due to the effect of windchill. There are between 10 and 60 days of frost per year in the plain and often fewer by the sea. Snowfall is rare and the population is not used to it. It rains between: 500 and 900 millimeters per year for 50 to 90 days.
- Oceanic climate in western France
  Rainfall is frequent, but of low intensity (between 120 and 180 days per year), humidity is high and temperatures mild.
- Modified oceanic climate
  There is less precipitation, winters are colder and there are more days of frost.
- Continental climate From north to east. Dry, harsh winters with snowfall.
  Mountain climate: (Vosges, Jura, Alps, Pyrenees). Because of the altitude, temperatures are lower and rain and snow more frequent.

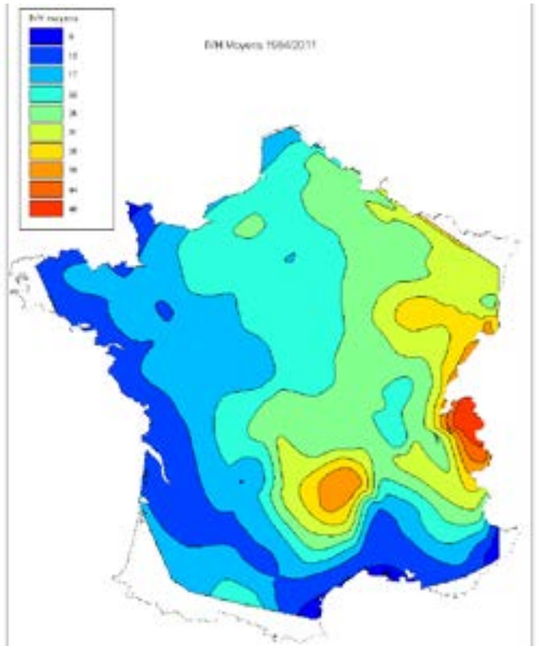
	T°C		Rainfall	
Climate	January	Days of frost	Annual amount (mm)	Number of days
Mediterranean	6 to 11°C	10 to 60	500 to 900	50 to 90
Oceanic	5 to 7 °C	10 to 60	600 to 1200	120 to 180
Modified oceanic	2 to 5 °C	30 to 70	600 to 1000	100 to 160
Continental	-1 to 1°C	60 to 100	600 to 1400	110 to 170
Mountain	-1 – to 4°C	60 to 120	800 to 1600	100 to 180

2.2 Winter index used in the country.

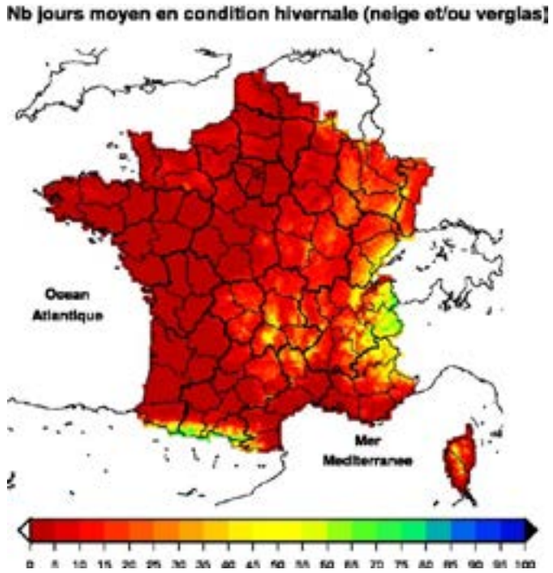
The winter road maintenance index (Index de Viabilité Hivernale - IVH) is an indicator of winter road network difficulties. It is built entirely around meteorological parameters obtained from meteorological station data.

The combination of these parameters gives the IVH and an image of the meteorological risk associated with road operation in winter.

The IVH100 is used to compare winters with each other and to monitor changes on a given site. A so-called average winter has an IVH100 of 100.



MANAGERS ALSO MAKE USE OF OCCURRENCES OF SNOW AND ICE:



AVERAGE NUMBER OF DAYS WITH SNOW OR ICE ON THE ROAD.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND REGULATIONS

Regulations

In France there is no legal obligation to carry out winter maintenance (WM). Managers do, however, have the duty of policing the safety and security of users and guaranteeing normal maintenance of the road for use as intended. Documents produced and distributed by the Ministry of the Environment, Energy and the Sea (Ministère de l'Environnement, de l'Energie et de la Mer - MEEM) set out general rules. The other contracting authorities (motorway companies and département councils) draw on the rules defined for national roads for their service levels, or develop their own specifications. These rules are formalized in the winter maintenance organizational documents (Winter road maintenance file and the Winter maintenance operating plan) (SETRA 2009 Guide Méthodologique Approche Globale).

Bad weather and snow plans are drawn up to deal with meteorological conditions (snowfall, freezing rain, etc.) that are likely to exceed the threshold conditions that can severely degrade traffic conditions on the road network. Their aims are to ensure the safety of users in all circumstances, to implement traffic management measures requiring coordinated action by departments in order to prevent the network from becoming jammed, insofar as this is possible, by ensuring that car traffic remains fluid even under degraded conditions, and to implement inter-departmental operational coordination arrangements with a view to providing assistance and even emergency help to affected users if necessary:

These plans define:

- the decision-making process to be set up according to the type of event
- the operational organization of departments to implement the decisions taken
- the various coordinated traffic management measures that can be applied according to the context encountered
- the organization of communication to users.

These plans may be local (département-wide) or zonal (covering a Defense and Security zone). The coordinating authorities for these plans are the département, and Defense and Security zone prefects respectively. They are supported by a COD (Centre Opérationnel Départemental - département operational center) and a zonal control center.

The objectives of a bad weather plan are to ensure:

- traffic flow even in degraded weather conditions, preventing users from getting stuck
- human safety by implementing inter-departmental operational coordination arrangements with a view to providing assistance or even emergency help to users.

The main measures defined in these plans concern:

- information to users
- traffic management
- assistance or emergency help to users

Defense and Security zone prefects and all those identified in the zonal bad weather patterns can use the AGORRA (assistance for operational management of road risks and hazards) web application for operational implementation of traffic management measures and monitoring them.

Standards for staff

European Directive 2003-88 of 4 November 2003 concerning certain aspects of the organization of working time, transcribed into French national law, structures the organization of work in both public and private sectors. The legislation proposes several forms of exemption to work organization rules to respond to specific situations. Performing winter service (working at nights and at weekends) comes into this context. The selection and implementation of an exemption to work organization rules requires discussion between staff representatives and the employer, and monitoring of health and safety conditions. As the consequences in terms of numbers and financial cost (on-call work, allowances, overtime, etc.) are linked to the organization adopted, the legislator has devolved this decision to local level. The principles are respected in highly heterogeneous fashion in small municipalities and companies.

Equipment standards

Standards for winter maintenance facilities and equipment have been produced.

NF P 98-180, use of sodium chloride as a road de-icing agent, specifications
XP P 98-181, This experimental standard aims to control all de-icing agents that can be used on roads, whether mineral or organic, by-products or even industrial co-products in liquid or solid form.
The latter two standards are in the process of being repealed and replaced by European standards.
NF P 98-792, winter road maintenance equipment, cab control position, characteristics and specifications
NF P 98-793, winter road maintenance equipment, terminology
NF P98-795, "Winter road maintenance and roadside maintenance equipment - Signage, marking and lighting of winter service response units - Characteristics and specifications".
NF P98-797, „Road maintenance materials and products - Road de-icing agent spreader - Stationary test method for flow measurement"
NF EN 15 432-1, „Winter road maintenance and roadside maintenance equipment - Front-end equipment - Part 1: fixed front base plates"
NF EN 15 432-2, „Winter road maintenance and roadside maintenance equipment - Vehicle interface for front-mounted equipment - Part 2: interchangeability of lifting systems"
NF EN 13021+A1 and IN1: Machines for winter service, safety requirements
NF EN 15597-1 „Winter maintenance equipment - Spreaders - Dosing requirements"
NF EN 15583-1 „Winter maintenance equipment - Snow plows - product description and requirements"
NF EN 15583-2 „Winter maintenance equipment - Snow plows - Part 2: Test criteria and requirements"
NF P 95-303, Anti-avalanche equipment, snow bridges, snow rakes, specifications and design
NF P 95-304, Anti-avalanche equipment, avalanche nets, specifications and design
NF P 95-305, Anti-avalanche equipment, avalanche nets, snow barriers, specifications and design
NF P 95-310, Anti-avalanche equipment, artificial triggering: technical principles
NF P 95-311 Anti-avalanche equipment, artificial triggering: explosive cable conveyors (catex)
NF P 95-313, protection against avalanches, gas activation

3.2 Organization and interventions

General remarks

In France the organization for road maintenance is as follows:

Contracting authority		Contractor
Transport department: National Roads (routes nationales - RN)	←	DIR road directorates operating across several French départements
Département councils : département roads	←	Département engineering departments
Cities: municipal roads	←	City engineering departments
Transport departments: concessionary highways	←	Highway companies

Whatever the contracting authority, the organization set up for winter road maintenance is set up along the same lines, which in most cases results in the production of a DOVH. This document is a kind of contract between the contracting authority and the contractor. It is used to inform the different partners about the objectives, the limits and the measures taken. It details the organization and the actions to be taken in each situation. The aim is also to ensure coherence between managers. The DOVH sets out the measures concerning road information.

Normal winter is generally defined from 15 November to 15 March and even from 1 November to 31 March for areas with severe winters.

Winter road maintenance services operate on average 14 days a year, from 0 to 150 days depending on the

years and zones. There are twice as many interventions by night than by day.

The involvement of public sector staff is relatively great for DIRs, cities and département councils.

DIRs comply with state requirements for the way they are organized. With concessionary highways, they generally have the highest level of service.

Winter road maintenance in urban areas is becoming more and more important. Organization is significantly improving and more and more consideration is given to intermodality in the strategies.

Driving conditions: the basis of a common language

The winter driving condition Ci which users may encounter solely due to the state of the roadway in relation to the presence of snow or ice provides the basis for a common language.

IT IS ONLY ONE OF THE POSSIBLE COMPONENTS OF A TRAFFIC CONDITION.

The driving condition Ci is defined as a function of the roadway states EC, themselves expressed as a function of the type of weather phenomenon.

	Ice	
Roadway States (EC)	Terminology of standard 99-320	Operational terminology
EC1	Dry, Transitory moist, Moist, Wet, Streaming wet	None
EC2a	White frozen, Frosted, Icy, Ice Localized or thin formation	Localized, thin formation of ice (by freezing of existing moisture or condensation) or ice patches
EC2b		
EC3	Frosted, Generally icy due to the freezing of supercooled droplets or freezing of preexisting water	Generalized formation of ice due to the freezing of existing moisture
EC4	Generally icy following precipitations on the road at below-zero temperatures or supercooled precipitations	Generalized formation of ice following freezing rain

Road conditions, example of ice

Road conditions (illustrative data, to be specified and adapted)			Winter driving conditions	Color code
Ice	Snow, no slope or incline	Snow, with slope or incline > 3%		
EC1	EC1	EC1	C1	Green
EC2	EC2a	EC2a	C2	Orange
	EC2b			
EC3	EC3	EC2b	C3	Red
		EC3		
EC4	EC4	EC4	C4	Black

Link between road conditions and winter driving conditions.

Definition of levels of service

The quality objectives defined are called levels of service (LS) This choice is defined by the various road owners and is expressed according to the type of meteorological phenomenon.

These service levels LS are based on the driving conditions Ci according to the following principle: in winter, a road has a reference condition compatible with the traffic on it and its geographical location. During a weather event, driving conditions will fall below the reference condition. At the end of the weather event, the service must restore the reference conditions within a

CHANGES IN DRIVING CONDITIONS AS A RESULT OF ICE

given amount of time. This response time is a quality indicator. For ice, the clock starts at the time the alert is issued; for snow, it starts at the end of the snowfall.

Levels			Li	Lii	
				Modality 1	Modality 2
Periods of validity					
Reference condition					
ice conditions	without precipitation	Minimum condition			
		Restoration time			
	with precipitation	Minimum condition			
		Restoration time			
Snow conditions		Minimum condition			
		Restoration time			

STANDARD FRAMEWORK FOR DEFINING LEVELS OF SERVICE

Average restoration times are:

short: 1 to 2 hours
average: 3 to 5 hours
long: over 6 hours
indefinite time

The minimum driving condition corresponds to the intensity of the most frequent bad weather conditions - snow or ice - on which the manager can take action. It therefore involves defining threshold weather situations beyond which it is considered that normal service can no longer be maintained (transition to crisis).

Parameters	Criteria and associated values
1 - Intensity of snowfall	Average hourly snowfall (non -melting snow), calculated over a three-hour period, at least equal to N cm/h
2 – Duration of snowfall	Continuous or intermittent snowfall (non-melting snow) at < 6-hour intervals, for a total duration of over N hours
3 – Snowfall and low temperature (during or immediately after, because of the risk of freezing and adhesion to the ground)	Temperature below – 8 °C during the snowfall or immediately after
4 – Freezing rain	Rain causing the formation of ice
5 – Wind and snowdrifts	Snow accumulation at a depth exceeding the capacities of the measures in place, over at least one lane and a significant cumulative distance (e.g. at least 100 m for 10 km of road)

CHARACTERIZATION OF A THRESHOLD WEATHER SITUATION

Organization of winter maintenance

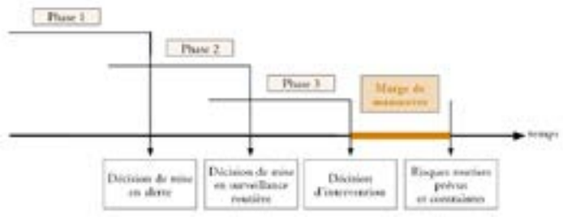
While the quality objectives or level of service LS are unique to each manager, the decision-making process is identical.

Three types of pre-response activity can be identified:

- Taking weather forecasts into account
- Collecting information on road networks
- Selecting the type of response.

These activities correspond to three decision levels, spread out over time with increasingly shorter deadlines:

- The decision to issue an alert
- The decision to monitor road
- The decision to respond.



Three phases can be identified:

- Qualified weather watch and the decision to issue an alert

- Close meteorological monitoring and the decision to monitor roads
- Detailed analysis of road hazards and the decision to respond.

Meteorological data, information obtained from SADSHs and observations from patrols are used to make decisions regarding whether response actions are needed.

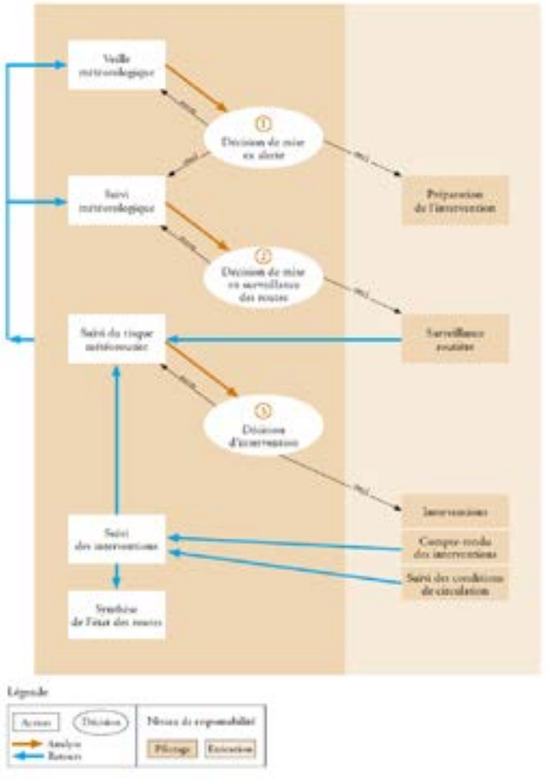
Equipment and organization levels can vary widely depending on the network managers. Sometimes, patrol officers can themselves decide to respond if they are alone at the operation center. Patrols can sometimes be made directly using response units, which then take action if necessary.

For each winter phenomenon, rules and procedures are defined, defining the people involved and the measures to be implemented.

The winter road maintenance plan (Plan d'exploitation de la viabilité hivernale - PEVH), which is the local version of the DOVH for operational centers, describes these procedures. All the procedures are described in detail, usually giving the following information:

- Various maps
  - roads and levels of service
  - patrol routes and control points
  - location of SADSHs
  - response centers and materials storehouses

  map with road conditions.
- Guides for:
  - the distribution and use of weather reports;
  - decision-making assistance
  - organization in exceptional situations.
- Other documents
  - patrol checklist
  - equipment and materials checklist
  - checklist describing actions (for decision-making and response purposes)
  - name and contact information of managers
  - instructions for pre- and post-winter actions.



Winter maintenance documents (DOVH and PEVH) regularly updated as part of a continuous improvement process. They are reviewed after each winter season (winter assessment and associated information) and re-validated for the following season in collaboration with trade unions.

RESOURCES USED

Meteorological information

Each local administration must purchase its local weather forecasts from a forecast service provider. There is no national contract and the information is not centralized. There are several weather forecasters including the „historic" provider Météo-France which is a state service. Basic weather information is also provided to the CRICR (organization responsible for road information and including peacekeeping forces (police, gendarmerie) and equipment). For the purposes of road safety, the CRICR may pass on the information to département services.

The different weather forecasting services usually provide the following weather information:

- Observations:

- radar
- satellite
- on the ground from Météo-France stations

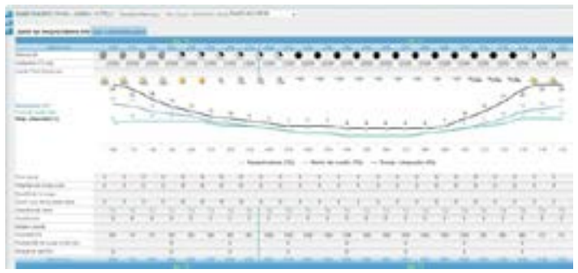
- on the ground from the operator's road weather forecasting stations
- the immediate forecast (extrapolation of radar images and precipitation discrimination)
  - the short-term forecast: D/D+1
  - the mid-term forecast: D+2/D+4

- the long-term forecast up to D+9

The parameters forecast are sensitive weather, air temperature, dew-point temperature, humidity, road temperature, precipitation (occurrence, type and intensity), thunderstorms, wind, cloud cover, fog, rain/snow threshold, snow height and snow quality.

These forecasts are provided in various forms (the examples below are from Météo-France):

- WM bulletin: bulletin drawn up by a forecaster and detailing the D+1 forecast for phenomena impacting roads in the operator's network. This bulletin also alerts as to the exceeding of thresholds defined by the operator (threshold meteorological situations for example). This bulletin is written up twice a day but can be sent as an alert if thresholds are exceeded between two updates;
- Highlighted weather maps: forecasts from D to D + 4 are given for several municipalities representative of the operator's road network;
- Interactive map with road sections colorized according to the value of the parameter represented (here, precipitation with snow in blue and rain in green); Atmogram: a table giving the forecast of several



WINTER MAINTENANCE DECISION SUPPORT SYSTEMS.

weather parameters up to J+4 and even J+9 in increments of 1h or 3h for a given forecasting point;

- Weather flash: Alert bulletin (written, email or vocal) on the forecast occurrence of weather phenomena that are hazardous for roads (e.g. snowfall, air temperature below -10 C, etc.) at times ranging from the next hour to D+1.

VEHICLE USED FOR THERMOHYDRIC SURVEYS

In addition, road operators can also contact a forecasting engineer directly by telephone to obtain information on the weather situation.

For road temperatures, Météo-France has developed a model providing Troadway forecasts in 1 km grid points over the whole of France.

These TRoadway forecasts can be improved on the forecast points corresponding to weather stations, by resetting the model in real time with the observations from Troadway and T in the ground of these stations.

Minimum weather information is also provided to zonal prefectures. For the purposes of road safety, the area prefectures may pass on the information to département services.

Winter maintenance decision support system (SADSH)

There are about 800 winter maintenance decision support systems (Système d'Aide à la Décision en Service Hivernal - SADSH), most of them on motorways or major roads.

There is no centralized information from these stations on a national scale. The information is sometimes centralized over an area and/or a region (for the same manager).

It is also possible to include meteorological station data in real time to take them into account in forecasts and weather information.

These information systems can be coupled with weather forecasts to produce road weather forecasts.

Choosing the location of an SADSH:

SADSHs are generally positioned in the most representative places, following the production of a thermohydric profile or based on the knowledge of the agents.

Patrols

Patrols are routinely sent out to the networks, for the purpose of recording information (road conditions, surface temperatures, etc.) enabling decision-making for precautionary and/or curative treatment.

TYPE OF WINTER SERVICE VEHICLE STANDARD IN INTERCITY ENVIRONMENTS

Response vehicles

The French standard for equipment used to fight ice and snow is: a carrier, equipped with a spreader and a front blade. However, because of their size and weight this equipment exceeds the general traffic rules imposed by the French Highway Code. French regulations have therefore adapted to this by creating a special status for this equipment:

- winter service vehicle (ESH). As defined in detail in the French highway code, the carrier may be a freight transport vehicle of more than 3.5t or an agricultural tractor. A decree lists the authorized tools and gives the maximum weights and dimensions allowed to come into this category. This recognition also allows certain waivers from the general rules of movement necessary for ESH mission best practice, such as being allowed to cross the central white line.
- Category N vehicles responsible for road maintenance are authorized to operate in the public domain with a frontal tool coupled to the front of the vehicle provided that the tool carrier interface is a base plate conforming to European standard EN 15432-1 and that the tool does not exceed the values defined in the decree.

There may still be significant differences in equipment depending on regions and types of networks.

Special rules for trucks

In France, almost all trucks are semitrailers and when a steep road (over 4% for example) is slippery, they cannot use it. On heavily trafficked roads, heavy goods vehicles (HGVs) often cause problems such as accidents and traffic congestion. The dissemination of information has greatly improved with the use of dynamic message signs (DMS) and radio (BP). Trucks are sometimes asked to stop and wait as part of the measures taken during bad weather plans.

On smaller networks, there is no dynamic signaling. On some roads, „white convoys" are organized. Approximately 10 trucks follow a response vehicle supervised by a police vehicle. Light vehicles (LV) can travel on the other lanes. But this system is difficult to operate when truck traffic is very dense and requires good coordination between the services providing WM and the police.

Traffic

Article R414-17 of the French Highway Code states that:

On roads, when at least one lane of traffic is covered with snow or ice over all or part of its surface:

1. Overtaking or changing lane is prohibited for drivers of vehicles whose total authorized weight exceeds 3.5 tons or for drivers of a group of vehicles whose length exceeds 7 meters;

2. Overtaking winter service equipment in action on the carriageway is prohibited for any vehicle.

Ploughing tools

The use of multi-purpose scraper blades is becoming widespread throughout the road network.

Materials

Sodium chloride remains the most used road de-icing agent (> 99%), in chemical form and as a moistened salt. For exceptional situations, such as very cold temperatures and freezing rain, some use solid NaCl and CaCl2 brine.

The proportion of brine and solid salt can be adjusted on the spreaders. The trend is to vary the proportion of brine according to the weather phenomenon. The most common practices range from 15% to 30% brine, and up to 100% brine.

This brine (water saturated with salt) is usually manufactured with water and NaCl at the response center. Very rarely used calcium and magnesium brines are generally delivered.

Salt consumption varies between 0.4 and 2 million tons per year, the average being 1 million tons. For pre-curative treatment, 15 g/m² are used on average. For curative treatment, between 25 and 30 g/m² are used on average.

Various documents on the optimal use of salt have been published at national level. They contain general information and advice, but no universal recipe. The amount of salt depends on the kind of road weather phenomenon. For example, the amount of salt to be spread will differ depending on the kind and amount of ice, etc.

Automatic brine spraying

This technique has been used in France for some twenty years, but relatively rarely because of its cost. These sprinkler systems are generally present on some motorway sections due to heavy traffic or on small sections of 100 to 300 m.

Snow fences

Snow fences are used preventively. A standard gives information about the choice and location (AFNOR 1992). Vegetation is also used. Th decision to set up a snow fence is made and funded locally.

Staff and training

Between 30,000 and 35,000 agents may be mobilized in all departments performing winter maintenance.

Standard jobs are identified for specific tasks.

- Response manager: responsible for the response equipment and, depending on the organization in place, may decide when to carry out response actions and informs the CRICR;
- Response authority or weather guard: centralizes all of the information available: meteorological, SADHS, patrols, truck drivers. Depending on the organization in place, he decides when to carry out response actions and informs the response managers;
- Patrol agent: verifies road surfaces and driving conditions, takes note of road weather parameters and observes any formation of ice;
- Response team or response unit driver: carries out response actions with the response units (spreaders and snowplows).

This organization is used for most managers. However, for small structures, functions may be accumulated due to the small number of staff: For example: The patrol agent may decide to respond.

Training and education

There is no engineer training or training school dedicated to winter maintenance. For the larger structures, training is organized internally: motorway concession holders have a training center and provide specialized training in winter maintenance.

Meteorologists are also asked to provide specific training on the use of weather forecasting for WM via the tools available to them.

For national roads, the training is organized in professional training centers (Centre de valorisation des ressources humaines - CVRH) and provided by the winter maintenance scientific and technical network (approximately 10 people). There are other public and private structures providing training. There is special training for newcomers and beginners' courses in more general training.

Operational issues

There is no general policy for winter service, but in general there are different activation states that depend on normal and abnormal situations

Backgro-und	Types of action		Remarks
Normal situation	Performing winter service by fixed service levels	With own resources only	Resources (staff and equipment) permanently available to the road operator. The decision to mobilize these is decided upon according to the present and foreseeable weather situation.
		With own and complementary resources	Resources which the road operator may use in addition to its own resources, systematically or based on the extent of adverse weather, using pre-established procedures and governed by contracts or agreements.
	Special traffic management measures		Provisions specific to these measures are defined in the TMPs and/or in adverse weather plans. These measures may be preemptively taken in normal situations and/or taken in abnormal situations
Abnormal situation	Winter service performed with mobilization of support services (3)		Resources that will be mobilized in addition to the organization's own and complementary resources in the event that the threshold meteorological situation is exceeded, following the provisions made in the Winter Maintenance Organization File (lists of resources, mobilizable companies, etc.), aiming for compliance with the levels of service, but without any guarantee regarding the often uncertain mobilization of support services.
	Temporary downward adjustment of service levels on part of the road network(3)		The aim here, if the threshold meteorological situation is exceeded, is to focus response actions (see the three types defined above) on a fraction of the network (a lane, number of lanes, etc.) designated by the owners of the road. The terms for the implementation of this type of measure must be defined in the DOVH and/or in the adverse weather plans.

Ice

On networks with a high level of service „pre-curative" treatment strategies are implemented, meaning that they are used just before the appearance of the phenomenon. These involve spreading road de-icing agents to prevent the formation of ice or to limit its adherence to the road if the phenomenon is intense .

Snow

Pre-curative treatment can also be carried out before snowy weather. The aim is to limit adhesion between the snow layer and the road surface covering in order to facilitate subsequent mechanical operations.

Ploughing is the most effective way to remove snow. Salt spreading, as well as traffic, are used to make the snow change into a more easily „ploughable" snow.

Removal techniques may differ from one manager to another, especially on multi-lane carriageways: the right-hand (or left-hand) lane may be cleared as a priority, the left-hand lane may not be cleared, etc.

Abrasives are sometimes used in mountainous areas. Mechanical sweeping is little used in France.

Abnormal situations

There are also bad weather plans to deal with crisis situations. Each plan defines:

- The coordinating authority, as well as the control center on which to base its action;
- The decision-making and coordination structure of the authorities involved;
- The operational organization of departments to implement the decisions taken;
- The organization of communication to users;
- The various coordinated operating measures that can be applied according to the context encountered.

Their objective is to ensure maximum safety for users, particularly during severe weather, by:

- providing information for users;
- road traffic management to ensure optimal traffic flow even under degraded service conditions;
- assistance and rescue operations for blocked users.

White roads

Some cities are beginning to adopt white-district strategies, i.e. ploughing for snow-related events and no chemical treatment. Low service level roads may undergo no winter maintenance treatment or even be closed. Abrasives are rarely used, except in some towns and in winter sports resorts (which are nevertheless using more and more road de-icing agents).

Porous asphalt

Porous tarmac is generally treated differently. An informational document explains the particular difficulties encountered with these surface coverings, and proposes methods for monitoring and treating them.

The average dosages are greater (between 50 and 100%) and there may be up to twice as many interventions. In the event of snow, motorway companies plan a ploughing operation every 20 minutes.

Thin asphalt concrete is also sometimes problematic. The only known solution is to plan more interventions and higher dosages.

Civil engineering structures

There are no regulations recommending special arrangements for the winter operation of bridges. There is, however, a set of measures contained in various documents or standards, intended mainly for the designers of civil engineering structures.

The use of non-corrosive de-icing agents to systematically treat all bridges is no longer justified today.

Recently built structures, or older ones that have recently undergone maintenance and upgrading, benefit

from modern constructive methods or protection techniques. For these, it is not necessary to use special non-corrosive de-icing agents.

The use of special non-corrosive de-icing agents is therefore reserved for metal bridges that have not undergone any particular maintenance over the past two decades or are showing signs of local corrosion.

Avalanches

There is a special organization for forecasting avalanches. Avalanche fences can be installed.

High-altitude weather stations (known as NIVOSE) record meteorological data and the characteristics of the snow cover In ski resorts, qualified staff take snow samples every week to examine changes to its various layers.

A model called SAFRAN-CROCUS-MEPRA which takes into account meteorological forecasts and the physical parameters of the various layers of the snow cover calculates the avalanche risk for a given point. The information is then broadcast to users using various means (TV, radio, etc.). When possible, avalanches can be provoked when there is a hazard.

3.3 EVALUATION OF RESULTS

Assessment of efficiency

A few years ago, the French Roads Directorate performed an assessment using the following parameters: salt consumption, cost per kilometer, number of man-hours for winter maintenance. User satisfaction surveys were conducted.

Inspections are sometimes performed to determine how directives are applied by the departments.

Analyses that are now fairly old were performed regarding the application of circulars and the quality of the DOVHs. The DIT (as the Roads Directorate is now called) has initiated thinking on the implementation of indicators, in particular user satisfaction indicators.

3.4 Road safety and information

Information for users

User information concerns:

- Information prior to the winter campaign
- Real-time information

Before winter, information is disseminated by road managers through various media such as radio and newspapers or in public places, town halls, etc. Maps showing the levels of service are distributed.

As part of the preparation for winter, the prefectures (département and zonal) also organize discussions with road professionals (local freight carriers and /or freight carrier federations).

Real-time information consists of delivering relevant and coherent information in real time to the greatest number of users concerned, thereby enabling them to adapt their behavior and to better accept the inconveniences.

The information is prepared based on a few main ideas:

- to be intelligible, information must reflect the general situation, from the meteorological data to the actions decided upon
- to be effective, information must be differentiated according to whether users are distant, approaching or in the area where traffic is disrupted
- to be credible, the information must not be discordant: the message drawn up at zonal level must be used by all the sources of information, possibly with clarification at the level of the département.

There are many channels for disseminating information in real time:

- radios
- real-time equipment
- websites
- new technologies (GPS, mobile phones, etc.)

As far as radio information is concerned, agreements between road managers and local radios and/or between the coordinating authority and local radios define how this information is to be disseminated.

DRIVING CONDITIONS AND USER INFORMATION

On the concessionary motorway network, the single radio frequency 107.7 broadcasts traffic information.

Real-time equipment (dynamic message signs) also allows operators to inform users about the traffic conditions they will encounter on their journey.

Road departments also have websites that display driving conditions in real time.

The “bison futé” website broadcasts a map of the entire national road network (concessionary and non-concessionary) to all users and carriers 24 hours a day:

- driving conditions
- traffic status
- events

New technologies allow fast and reliable information to be disseminated (spreaders equipped with GPS, mobile phones, etc.), as well as targeted information for users based on their location and destination. Bison futé makes all the information it collects available to any operator.

4 Ongoing Research and Studies to Improve Winter Management

4.1 New technology and research

Research projects in the field of winter maintenance have experts in methodological and organizational approaches working closely together. Some of these projects aim to define more exactly the road conditions (ECi) used to define levels of service.

Further work is being done in the study of how de-icing agents transfer to natural environments through the assessment of road runoff water treatment systems and investigation of opportunities to improve treatments of road de-icing agents.

Research projects currently underway include:

Alert prediction system

On-going research on the development of an on-board warning/forecast system for vehicles integrating connected vehicle data in real time: an experimental campaign is under way between Météo-France and an automotive supplier comprising 200 connected vehicles spread throughout France to:

° define methods for taking into account data from vehicles (temperature, wipers for precipitation, ESP/ABS for surface condition, headlights for visibility, etc.) to enhance meteorological observations

° send meteorological information about the route (alerts forecasts) to vehicles

Environmental impacts of road de-icing agents:

*Monitoring of road runoff containment ponds: assessment of the quantities of pollutants (de-icing agents, heavy metals) entering and leaving these ponds, study of the physico-chemical processes involved;

* Development of water pollution control solutions based on phytoremediation: laboratory tests, development of a methodology, preparation of in situ tests in progress (planting halophilic plants in the ponds);

* Development of a methodology for the mapping of pressures due to road de-icing agents.

Impacts of de-icing agents on the aging of materials:

* Development of the Prototype for Observation of Corrosive Reactions - Study by Cyclic Immersions (PORC-EPIC);

* Development of tests to monitor corrosion kinetics.

- Improved numerical tools for predicting surface temperature (ice frequency susceptibility maps, statistical approach based on multiple linear regression),
- Thermolog, a software program for determining road susceptibility to icing, based on the thermohydric signature of a route, which helps managers to install signs and road weather stations,
- Tools for determining weather visibility by using a road camera and an infrared camera to access a visibility distance in meters,
- Improved on-board vision systems for driving assistance with methods for restoring images in the

ODEMIE device

presence of rain and estimating visibility by image processing
- Prototype for measuring residual salinity on surfaces, and software for assessing the amounts applied
- Photo processing software to assess the amount of salt spread by a winter service machine. This helps to quantify the longitudinal and transverse homogeneity of a spreading operation
- Device for determining the thermo-physical characteristics of the road infrastructure materials (thermal radiative)
- Adjustments to the software for predicting the temperature and surface condition of the carriageway adapted to the routes, with a module dedicated to de-icing agents, in association with Météo France
- Development of tests to verify spreaders (ODEMIE devices)
- Experiments on the guidance of winter maintenance units (WM) (GSM/GIS);
- Development of test protocols to evaluate the „use value" of de-icing agents.
- Roadways with frost-free surfaces

The research action „Roads with frost-free surface" concerns the study of heating roadways based on the use of porous asphalt, in a binding layer, allowing a heat transfer fluid (water) to circulate in order to prevent snow from sticking or ice from forming. In particular, the possibility of incorporating such roadways into year-round self-sufficient energy loops, enabling solar energy to be captured and stored (in the ground) during hot or sunny periods, and released according to winter maintenance requirements. For certain critical points, the challenge is to increase the levels of service, reduce the material and financial resources devoted to winter maintenance, and to reduce the amount of salt applied to road surfaces and the effects of this: vehicle corrosion and pressure on the environment. A demonstrator set up by Cerema has been operational since 2015 in Egletons, Corrèze. Complementary work on storage by phase change materials is also under way, making particular use of spectroscopic skills and the use of climatic chambers. It should be noted that this issue of heating roadways is part of a more general one concerning roads and energy. Innovation-related activities also address the issue of freeze/thaw cycles, leading to severe degradation of the road network. Work begun a year ago attempts to evaluate the addition of a non-toxic chemical compound to snow removal salt in order to reduce the swelling of water as a solid phase in the upper layers of the roadway. A partnership between a Dutch industrialist, Cerema and DIRMC was set up in 2016.

4.2 New management and organizational approaches

The methodology for defining levels of service was updated in 2009 and a new circular regarding its application for the national road network will be released shortly,

Snow plans and traffic management plans are operational.

Sustainable development and Environmental impact

There is no substance with zero environmental impact. Even so-called „green", „ecological", or „environmentally friendly" products have negative impacts on the environment, mainly due to the way they are manufactured. Even when particular attention is paid to manufacturing processes in order to lessen their environmental consequences, no process is totally neutral. This is because all products need raw materials and energy to be manufactured. All products must be packed and transported. And even if it is recycled several times, any product or packaging will eventually become waste. The challenge is therefore to identify which product has less impact than another used for the same purpose. The ecological quality of a product is characterized by all the environmental impacts caused by the product throughout its life cycle.

The concept of environmental impact refers to all qualitative, quantitative and functional changes in the environment (negative or positive) generated by a project, by a process, by organisms and by products, from design stage to their end-of-life. The assessment of an environmental impact is quantified through the measurement of potential flow indicators and potential impact indicators.

For air, five indicators are used:
- contribution to the greenhouse effect;
- acidification of air
- tropospheric ozone formation
- depletion of the ozone layer
- particles and respiratory effects caused by inorganic substances.

For water, four are used:
- eutrophication of fresh water
- aquatic ecotoxicit
- eutrophication of marine water
- water consumption (flow indicator).

For soil resources and human health, the following four indicators are used:
- primary energy consumption (flow indicator)
- depletion of non-renewable resources
- human toxicity
- land use.

4.3 Transnational cooperation to improve service levels between neighboring countries

Strong cooperation exists at European level and the work of COST 353 has helped lay the foundations for thinking on European service levels. Standardization work is being carried out at European level.

There is cooperation with the Quebec Ministry of Transportation on road de-icing agents and the environment. A joint report is currently being prepared and will serve as a guide for further thinking on this subject.

5 REFERENCES

A website to collect knowledge in the field of winter maintenance is operational and accessible to all.

http://www.viabilite-hivernale.developpement-durable.gouv.fr/

Glossary

DOVH : Dossier d'organisation de la viabilité hivernale (Winter road maintenance organization file), a document about the organization of WM.

PEVH: Plan d'exploitation de la viabilité hivernale (Winter road maintenance plan), the local version of the DOVH

DIR: Direction interdépartementale des routes (Inter-département road directorate), an operational delegation coming under MEDDE CRICR: Centre régional d'information sur la circulation routière (Regional information center on road traffic). Organization run by the Ministry, the police and the army, which centralizes road information and informs users.

MEDDE (French Ministry of Ecology, Sustainable Development and Energy)

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Germany in the centre of Europe borders on the Netherlands, Belgium, Luxembourg, France, Switzerland, Austria, Czech Republic, Poland and Denmark and has sea accesses to the North and Baltic Sea.

The Federal Republic of Germany, consists of 16 Federal States, the 3 „City-States" (Berlin, Hamburg, Bremen) included, whose territories are of different size between 71.000 km² (Bavaria) and 2.700 km2 (Saarland). Each German State has its own constitution and public authorities. Road Authorities exist in each State.

Area		356,700 km²	
Latitude		47°16' to 55°03'N	
Population		82.80 million	
Length of road 2002-12-31	Federal trunk roads	Federal motorways (Autobahnen; 4- and 6- lane divided highways)	12,80013.000 km
		Federal highways	40,60038.300 km
	Other federal -aid roads	State highways	86,600 900 km
		County roads	91,500 900 km
		Community / urban roads	413457,000 km
	Total		68544,1500 km
Capital		Berlin	
Latitude		52°30'N	
Inhabitants		3.52 million	

MAIN ROAD NETWORK IN GERMANY (MOTORWAYS RED)

1.2 ROAD NETWORK AND TRAFFIC

During the past decades Germany was faced with an enormous increase of traffic on the highways. Today passenger traffic (passenger-km) on the road amounts to more than 90 %, commercial traffic (tons of merchandise-km) to about 7067 % of the total traffic while the remainder traffic distributes itself to other travelling and transportation modes, i.e. on rail, water ways or air. Motorways in Germany (so called „Autobahnen"); all together 12.80013,000 km, carry more than 40 % of the total traffic of the entire classified rural, interurban road net (consisting of Federal Motorways, Federal-, and State-Highways and County roads), although they represent only about 6 % of the total length of this road net.

The enormous increase of traffic volumes in recent years will continue even more rapidly in future time as a consequence of the ongoing political and economic developments, especially the European process of unification. The extension of the European Union to the east is expected to bringhas brought another great amounts of traffic to the „transit-country" Germany within the nextin the last years due to intensified economic cooperation's.

The extension of the road network in the last years and also in the near future does not correspond to the increase of the traffic so that traffic volume on the roads and congestions raise up.

Maintaining traffic safety, optimum driving conditions and availability of sufficient capacity of highways all around the year, even during winter season is of crucial importance, especially for the economic development. As a consequence in future road operations and especially winter maintenance will become much more important.

The State Road Administrations are in charge of planning, construction and maintenance including winter maintenance for Federal motorways and highways and for State highways. The Federal Ministry, respectively Department of Transportation has the right of legal and technical supervision for the federal trunk roads.

Road Class		Property and financial obligation for planning, construction and maintenance	Administration of planning, construction and maintenance
Federal trunk roads	Federal motorways	Federal government	Federal states on behalf of the federal government
	Federal highways		
State highways		Federal States	Federal states
County roads		Counties	Counties partially federal states on behalf of counties
Community / urban roads		Communities / Cities	Communities / Cities

Due to a legal renewment in 2017 in future the Motorways will be planned, constructed and maintained

Meteorological Stations (close to motorways) (m above sea level)		Meteorological Data (Average d-30 years) - Main Winter Months -									
		Average daily minimum temperatures [° C]				Average precipitation[mm]					
		Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.	Total	Total year
1	Kiel (17 m)	- 0,3	- 2,1	- 1,8	0,4	74	65	40	54	233	777
2	Schwerin (59 m)	- 0,9	- 2,6	- 2,1	0,3	55	46	33	42	176	620
3	Hannover (53 m)	- 0,7	- 2,2	- 2,0	0,3	60	52	37	48	197	665
4	Berlin (48 m)	- 1,0	- 2,7	- 2,1	0,7	53	43	34	37	167	584
5	Bonn (62 m)	1,0	0,0	0,5	2,6	52	47	37	46	182	678
6	Erfurt (312 m)	- 2,2	- 3,6	- 3,4	- 0,5	30	25	26	36	117	492
7	Frankfurt (112 m)	- 1,0	- 2,1	- 1,6	0,9	54	44	40	51	189	658
8	Hof (474 m)	- 3,3	- 5,0	- 4,5	- 1,8	63	53	44	47	207	708
9	Stuttgart (373 m)	- 2,2	- 3,3	- 2,4	0,3	48	44	42	44	178	719
10	München (527 m)	- 3,7	- 5,1	- 4,0	- 0,8	60	53	52	56	221	967
11	Villingen – Schwenningen (720 m)	- 3,5	- 5,0	- 4,5	- 2,5	85	77	74	68	304	915
12	Kempten (705 m)	- 5,1	- 6,2	- 5,0	- 1,9	90	83	78	79	330	1273
13	Bad Reichenhall (455m)	- 4,0	- 6,5	- 4,5	- 1,0	128	125	110	120	438	1665
14	Garmisch-Partenkirchen (719 m)	- 5,7	- 6,5	- 5,1	- 2,3	92	85	77	96	340	1364

no more by the Federal States, but by a central Federal Motorway Company, beginning in the year 2020.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

Germany has a moderate climate, often weather changes are characteristic. From the low lands in the northwest to south eastern regions there is a gradual transition from maritime to continental climate. Mostly western winds and precipitation during the whole year are characteristic. Typical are frequent cold (continental) winds and snow storms, from eastern European in south eastern Germany. In the northern lowland the yearly precipitation amounts to 500 mm to 700 mm in the lower mountain ranges, in the middle part of Germany between 700 mm and 1500 mm and in the south, close to the alpine region up to 2000 mm.

The daily and yearly temperature variations are not extreme, except in south eastern Germany and in the alpine region. The average temperatures in January vary from + 1,5°C and – 0,5°C in the lowlands, in the alpine region the average temperature may get below – 6°C, depending on the altitude (see Table above).

Typically for the German climate is the often change of temperature around 0°C with freezing and thawing periods following each other. This brings many problems for winter maintenance.

There is snowfall to a larger extent only in mountainous regions and the surrounding areas. Bavaria, the most southern State including the north edge of the Alps therefore is the most „snowy" region in Germany with winter maintenance from November to April, whereas in other parts of Germany there is a shorter winter period. In the Northern Parts of Germany spreading is more dominant than snowfall. But here also appear sometimes very heavy snowfalls in short time.

But even in Bavaria there are great differences concerning the amount of snowfall in different parts of the State as follows (table)

Large parts of central and northern Germany receive th e same amount of snow as the lower areas and river valleys in southern Germany. Other typical features of the climate are the great variation in the severity of consecutive winters, in relation to temperature and amount of snowfall. Main problems for the winter maintenance management are the often temperature changing around 0°C or short heavy snowfalls.

State of Bavaria	Annual cumulative snowfall (measure at motorway maintenance stations)	
	average of the last winter periods	Maximum: Winter 2005/06
Front of alpine region	440 cm	1030 cm
Lower mountain regions	210 cm	645 cm
Lower areas, river valleys	50 cm	125 cm

2.2 Winter index

The Federal Highway Research Institute actually makes researches to define a winter index in order to find a correlation between winter severity and salt consumption necessary for snow and ice control, and to prove the effectiveness of pre-wetted salt technology.

This index is also important to calculate the storage amount of salt needed for strong winter periods for each region.

The Investigations show that most relevant for salt consumption is the amount and frequency of snowfall in the snowy regions. In regions with less snow there is a relevant factor the number of temperature changings around 0°C

3 WINTER ROAD MANAGEMENT

3.1 STANDARD AND RULES

The legal obligation to do winter maintenance results from a general duty out of the German Civil Code. It is reduced also defined in the federal laws (Bundesfernstraßengesetz) and, the state laws (Straßen- und Straßenreinigungsgesetze der Länder) and in the statutes of the cities.

Regulations about the requirements, organisation and realization of winter maintenance are given in the Guidelines for Winter Maintenance Performance (MerkblattRichtlinien für den Winterdienst auf Straßen, 2010).

For snow clearing vehicles the following service cycle time-periods for motorways and highways are stipulated:The levels of Service for the different types of roads ("Anforderungsniveau Winterdienst") are shown in the following table. The circulation times for the main roads are regulated as follows:

- Motorways and highways, 2 hoursserved 24 hours a day
- Circulation time for spreading 2 hours
- Circulation time for snow removal 3 hours which in connection with the (daily 24 hours) motorway-network have a bsignificant traffic function
- motorway interchanges 2 hours (daily 24 hours) federal and state 3 hours
- highways (daily 6 am to 10pm)

For pure salt spreading activities distinctly shorter time-periods are standard. The Level of Requirement for Winter Maintenance is given in Table below.

On sections with steep grades and/or special traffic shorter circulation times are recommended but not special regulated.

There is an actual research project ongoing to evaluate the effects of heavy snowfalls on traffic and the needed maximum circulation times on different road types.

Level of Requirement for Winter Maintenance

road with traffic function	period of traffic stand by	weather or road condition		
		snowfall, icy roads, hoarfrost	heavy continuous snowfall	Severe drifting, avalanches, freezing rain
1 Federal motorways and additional stretches of highways, which in connection with the motorway-network have a significant traffic function	24 hours (daily)	trafficability on through lanes, interchanges, ramps in junctions and interchanges; passability on parking facilities, shoulders	trafficability on at least one through lane per direction of traffic, the most important ramps in junctions and interchanges as well as access roads to service areas, if required with snow chains; passability on parking areas without service cannot be any longer guaranteed.	trafficability cannot be any longer guaranteed
2 important rural roads, roads with strong rush hour traffic, roads with public transport	from 06.00 a.m. to 10.00 p.m. (daily)	trafficability	trafficability, if required with snow chains; on mutilane highways at least one through lane per direction of traffic, if required with snow chains	
3 Further rural roads	appropriate to local traffic demands	trafficability	trafficability, if required with snow chains	
4 sidewalks, bicycle route, multipurpose lane	appropriate to local traffic demands	trafficability, usability for pedestrians	trafficability cannot be any longer guaranteed	
5 parking facilities in connection with important and other roads (row 2 and 3)	appropriate to local traffic demands	passability	passability cannot be any longer guaranteed	

"trafficability" means that obstructions as a result of remaining snow or – according to duration of winter maintenance operation - locally uniform snow covering must be expected, similarly possible local occurrence of slippery roads as a result of hoarfrost or icy roads even after spreading.
"usability for pedestrians" demands that one lane is kept clear of snow and ice to allow two pedestrians to pass each other carefully (approx. 1,0 to 1,2 m).
"passability" on parking facilities and shoulders means that access roads and lanes on parking facilities and shoulders can be used with an adjusted driving behavior appropriate to existing obstructions and that proper parking is possible.
"appropriate to local traffic demands" means that winter maintenance is carried out at times demanded by specific traffic. In the individual case this may mean that no winter maintenance is carried out.

3.2 Organisation and Operation of Winter Maintenance

Organization and planning of winter maintenance activities have to be done early and comprehensively because the exact beginning and extent of the coming winter is nearly unforeseeable. Winter maintenance has to work effectively and efficiently from the very beginning of winter. Only careful planning guarantees a most economical realization of winter maintenance. Therefore following plans must be made in advance:

Priority Plans

These plans regulate the priority and intensity of treatment of the various routes of the road network and prescribe which gritting agents – deicing or abrasive agents – are to be used on theses roads.

A priority list is necessary, especially in urban areas because there winter maintenance can be carried out

only successively and not everywhere at the same time. Useful criterions are:

- road category (motorways, federal highways etc.); in cities major, secondary roads, residential streets,
- traffic volume (average daily traffic),
- special traffic (roads with public transport or school bus traffic, access roads to rescue service stations etc.)
- special accident prone spots (steep grades, dangerous curves and crossings, stretches with frequent slipperiness in winter such as bridges, roads through forests, extremely shady roads).

Plans for snow clearing and salting

These plans assign crew and vehicles for winter maintenance activities to certain routes and in certain sequences.

For different weather conditions or different tasks there exist different plans.

Schedule for standby of personal, working shift plans

These plans regulate on a day-to-day or week-to week basis, which personal has to be appointed to standby for short term readiness outside of regular working time, in order to meet the Level of Requirement for Winter Maintenance. The 24 hour service on motorways requires shift plans.

Snow and Ice Control Strategy

The strategy persuade in Germany on rural and main urban roads in connection with winter maintenance activities is to achieve again „black" i.e. snow-and-ice-free pavements as soon as possible, with the aim of maintaining traffic flow as long as possible and to improve road safety: so-called „bare pavement policy".

In cases when icy roads can be expected in the near future depending on the weather forecast this policy leads to preventive salt spreading which has become standard been more used in the last years.

On secondary and lower rank roads in urban areas and in municipalities, in general, where lower driving speeds are prevailing, „differentiated winter maintenance" is performed. According to the function and the traffic volumes of these roads and streets and depending on weather conditions there is a gradation in the winter maintenance policy: application of de-icing agents on major roads and so called „zero-spreadinggritting" e.g. only snow clearing, on the lower, the residential streets.

Gritting with abrasive matters on roads which was used in former times has become very less common in the last years. A study on behalf of the German Umweltbundesamt (Federal Environmental Agancy) has shown by screening of life-cycle analysis (LCA) that de-icing materials in total have less negative ecological effects than abrasives. And other studies concerning traffic safety showed that de-icing materials lead to a much lower accident risk on main roads and steep grades in urban areas. On residential streets with very low and slow traffic there is no safety problem without any spreading.

For optimization of winter maintenance management actual information and forecasts about weather and road conditions are necessary. Detailed road weather observation and surveillance by the nationwide Road Weather Information System – RWIS ("Straßenzustands- und Wetterinformationssystem – SWIS") is standard today in Germany. RWIS combines synoptic extensive weather forecasts of the German Weather Service (Deutscher Wetterdienst – DWD) with data based on local meteorological stations and ice detection installations throughout the road net. The results are separate forecasts for areas with different local climates. The DWD provides several times a day very detailed middle term (3 days) and short term (24 hours) road weather forecasts to the road maintenance stations. In addition weather warnings are issued for sudden critical occurrences, which are not yet included in the general road weather forecasts. Information is distributed by computer network and reach directly the RWIS-computers in the maintenance stations. Improvements are on the way to extend the service by installing meteorological surveillance stations and pavement sensors for ice detection at all critical points of the road net. At present roadside meteorological stations exist mainly on motorways, but also on other rural roads, more than approximately 1,000 installations in Germany.

Additional the surveillance centres get information and data of their roadside meteorological stations with atmospheric and surface sensors.

Following data are measured and provided:

- air temperature
- road surface temperature
- relative humidity
- dew point (calculated out of air temperature and relative humidity)
- precipitation (type, intensity)
- road surface condition

Guidelines for Spreading Dosages

In former times there existed only overall recommendations for the salt dosage depending on the different road and weather conditions.

In the last years there were developed different recommendations on the basis of practical experiences, several research projects and special calculations. They were established in New Guidelines (see the following table). They regulate spreading amounts of pre-wetted salt and full wet spreading. Preventive spreading is recommended every time when possible, that means when weather forecast is clear (freezing moisture, hoarfrost and black ice). In these cases full wet spreading is recommended.

optional:

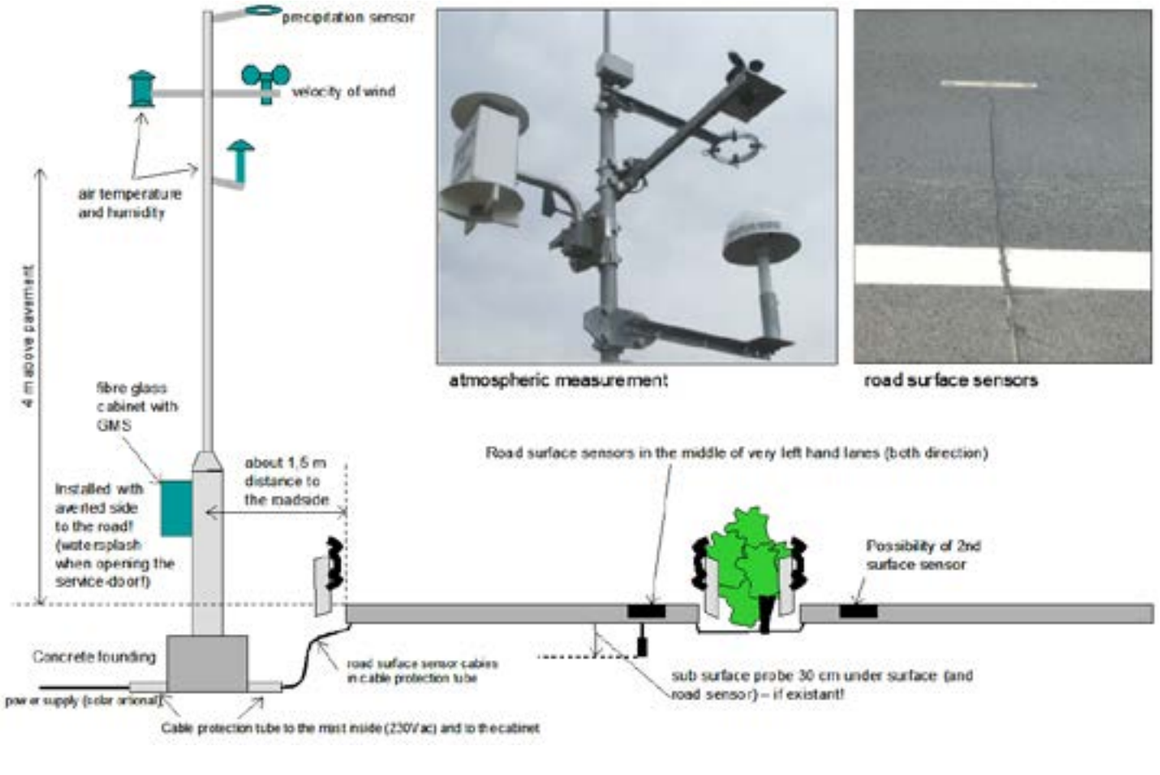
- road structure (sub surface) temperature in various depths
- wind (direction, speed)
- freezing temperature
- residual salt

3.3 Assessment of Snow and Ice Control Measures-Salt Consumption and Winter Maintenance Costs

According to variable climatic conditions in consecutive winter periods salt consumption and expendi-

Expected Surface Condition	Recommended Winter Maintenance Action	Recommended Spreading Density ***
Hoarfrost	Preventive Spreading** - preferential Liquid Spreading* - otherwise Pre-Wetted Salt	10 – 15 ml/m² 5 – 15 g/m²
Light Black Ice (freezing moisture)	Preventive Spreading** - preferential Liquid Spreading* - otherwise Pre-Wetted Salt	10 – 25 ml/m² 5 – 30 g/m²
Black Ice (freezing wetness)	Preventive Spreading** - Pre-Wetted Salt or Liquid Spreading*	15 – 40 g/m² (20 – 50 ml/m²)
Freezing Rain (black ice)	If possible Preventive Spreading** - preferential Liquid Spreading* - otherwise Pre-Wetted Salt	40 – 60 ml/m² 30 – 40 g/m²
Snow Fall (packed snow)	1. Where possible Preventive Spreading with Liquid Spreading* or Pre-Wetted Salt 2. During Snow Fall Snow Removal and Spreading of Pre-Wetted Salt with low spreading density 3. After Snow Fall aggressive Removal of Snow and Spreading with Pre-Wetted Salt	15 – 30 ml/m² (10 – 20 g/m²) 10 – 15 g/m² 20 – 40 g/m²
	* *Liquid Spreading only at temperatures above -6°C, at lower temperatures only Pre-Wetted Salt* ** *if preventive salting was not possible, existing slipperiness must be eliminated with Pre-Wetted Salt with double spreading density*	*** *low values for temperatures tight below 0°C, higher values for lower temperatures*

Table: German Guidelines for Spreading Policy



atmospheric measurement

road surface sensors

tures for winter maintenance show large differences as follows. All data is given for motorways and federal highways.

It is evident that the last winter periods were mainly stronger than these beforesalt consumption and the winter maintenance costs are rising over the years, but with strong variances. . Especially between 2009 and 2013 the values were very high. There were long periods with heavy snowfalls, often expanding over the whole country. This leaded to high salz consumptions and winter maintenance costs.

There In these winter periods there were problems with the salt delivery for many weeks. As result of the experiences in the winter periods 2009/10 and 2010/11 there were elaborated new guidelines for salt storage and salt management. Following this the storage capacity for salt was nearly doubled up to 2012, from 1,2 Mio. Tons up to 2,4 Mio. Tons now.

As average over the last 5 years there were spreaded 3248 t per km motorway and 1116 t per km highway each winter period. On motorways were spent 809500 € per km each winter period, on highways 25900 € per km.

These values are more than double of the50 % higher than the averages before the year 2000.of the last 20 years before.

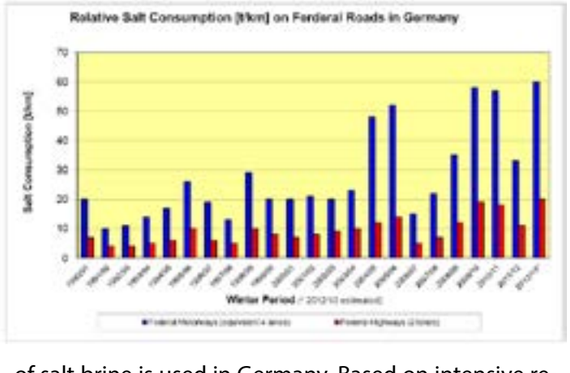
There is no special budget for winter maintenance, only a yearly budget for road maintenance. Yearly variable expenditures for winter maintenance have to be covered by the budget for road maintenance. This means, that after extreme winters even other road maintenance tasks have to be postponed to a certain extent; after extreme strong winters even additional funds from the construction budget are necessary.

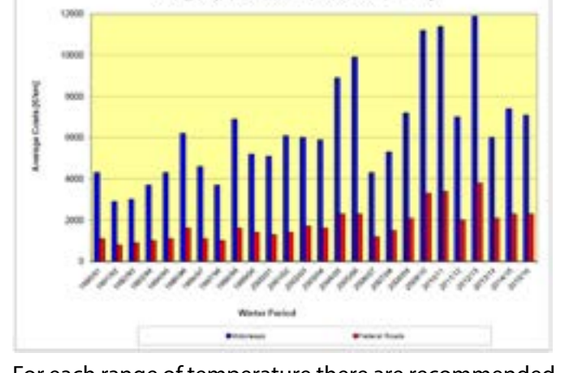
3.4 Actual Research and Development

In the last decade a lot of research was done to optimise winter maintenance and to decrease the expenditures and environmental impacts.

Pre-wetted salt ("FS 30" with 30 percent brine) is today standard technique in Germany.

But in the last years more and more full liquid spraying





of salt brine is used in Germany. Based on intensive research and practical experiences it is clear that liquid spraying is the best practice for preventive spreading at temperatures round 0°C.

The new winter maintenance removal and spreading strategy in Germany is shown in the following table.

Expected Road Condition	Recommended Winter Maintenance Strategy
Hoar Frost	Preventive Spreading - preferred Liquid Spreading* - otherwise Pre-Wetted Salt
Freezing Moistness	Preventive Spreading - preferred Liquid Spreading* - otherwise Pre-Wetted Salt
Freezing Wetness	Preventive Spreading - Pre-Wetted Salt or Liquid Spreading*
Freezing Rain	If possible Preventive Spreading - preferred Liquid Spreading* - otherwise Pre-Wetted Salt
Snow Fall	1. If possible Preventive Spreading with Pre-Wetted Salt 2. During Snowfall Snow Removing and Spreading with low salt density 3. After Snowfall intensive Snow Removing and Spreading with Pre-Wetted Salt
	*Liquid Spreading only to temperatures down to -6°C

For each range of temperature there are recommended spreading densities in the new guidelines published in 2012.

With Following the new Winter Maintenance Policy (see Chapter 3.2) this strategy liquid spading will be used very often in Germany in future.

The winter maintenance operators will change their fleet from only pre-wetting machines to a combination of liquid and pre-wetting spreaders. Liquid spreading can be done by machines which are specialized for this or with combined spreaders which can do both, liquid and pre-wetted spreading.

It depends on the special situation what machines are the best. Normally on motorways special liquid -spraying machines are used, on rural roads and in cities more combined-spreaders.

Also on bicycle paths there is used more and more full liquid spreading in Germany. There are several pilot projects with good experiences. This is very important because bicycle use is rising in Germany, also in winter time. On icy or snow-covered bicycle lanes the accident risk is much higher than on salt-spreaded lanes.

COMBI-SPREADER WHICH CAN SPREAD BOTH: PRE-WETTED SALT OR BRINE ONLY

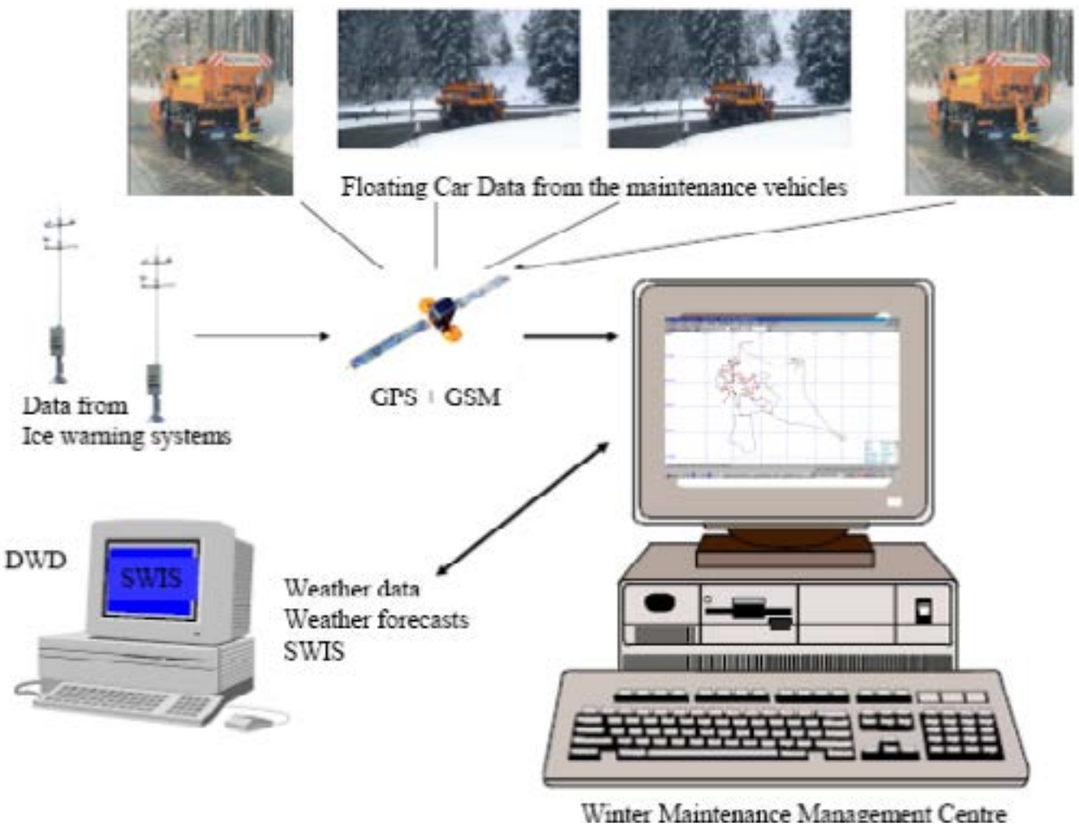
3.5 Traffic Safety and Information

Information concerning weather forecast and road conditions is available on several systems such as radio broadcast, television, internet and telephone. Additionally, drivers will be informed by radio broadcast, if chains are necessary or if truck drivers, especially drivers of trucks with dangerous loads, have to stop at the next parking place or rest area.

In mountainous regions traffic signs give information, wether mountain passes are closed and whether winter tyres or chains are obligatory.

On several motorway sections variable road signs of traffic control systems are also used for traffic safety, for example during snowfall or during slippery conditions.

Winter Maintenance Management Systems are builded more and more in the German States. When using all actual information from RWIS, from ice warning systems and from the maintenance vehicles (floating car data) an improved winter maintenance is possible.



ICELAND Version 2014

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Area	103,000 km²
Latitude	64°08´N
Population	320,000
Density	3.1 per km²

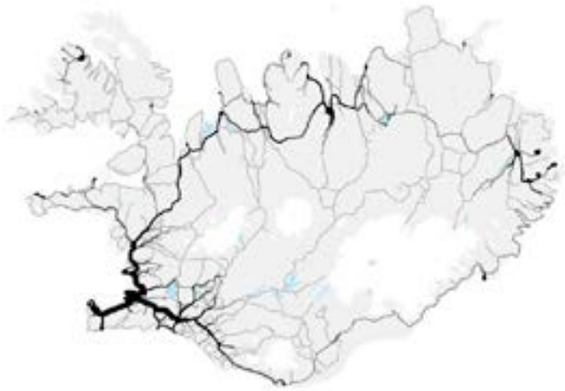
Iceland is situated in the middle of the North Atlantic Ocean, approximately 290 km east of Greenland and 970 km west of Norway. Consisting mainly of a plateau, Iceland's average height above sea level is 500 m, the highest point being 2,110 m. Only one quarter of the country lies below the 200 m contour line. The island is mountainous, surrounded by coastal lowlands, fjords and valleys shaped by marine abrasion and glacier erosion.

The economy depends mainly on export of products from power intensive manufacturing (24%), fishing industry (27%) and tourism (20%). The road network plays an important role in local transport of marine products for processing and export and for the increasing tourism.

1.2 ROAD NETWORK AND TRAFFIC

The Icelandic Road Administration, ICERA, is responsible for the road network, whereas the municipalities take care of roads within populated areas. The ICEARA road network includes 12,898 km, thereof 5,252 km of paved roads. The road network is divided into:

Road type	Length of road
Total ICERA road network	12,898 km
Primary roads	4,425 km
Local access roads	3,091 km
Primary highland roads	505 km
Highland roads	1,921 km



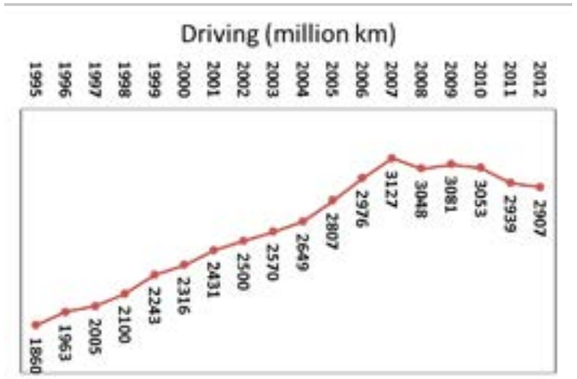
Primary roads connect areas of 100 or more inhabitants, secondary roads interconnect primary roads or connect primary roads to mountain roads, smaller villages and popular tourist destinations, local access roads connect farms or public places outside of populated areas to secondary and primary roads, and finally primary highland roads and highland roads, across mountains and moors, with limited service and often closed in winter.

Most of the traffic finds place in a 40 km circumference around the capital area in the southwest, where approximately half of the population is living. This map shows the traffic distribution on the road network:

Number of vehicles by December 31st 2012:

242,500 vehicles total, thereof
210,000 passenger cars
32,500 commercial vehicles

Heavy vehicle commercial traffic has increased considerably since sea transport along the coast ceased by the end of year 2004. However, traffic growth has ceased following the economic recession. The following diagram shows estimated total traffic on the Icelandic road network.



2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS, MAIN WINTER EVENTS TO BE MASTERED

Iceland has an oceanic climate and doesn't undergo the extreme temperature conditions of continental climates. The winters are mild, but the summer is cool. There is a considerable difference between respectively the coastal lowland climate, the climate of the main highland plateau and the climate of the highest mountain areas.

There is also some difference between the north and south. Temperature decreases and precipitation increases with height above sea level. The north of Iceland is generally cooler than the south in wintertime and has more snowfall while mid-winter rainy periods are more frequent in the south.

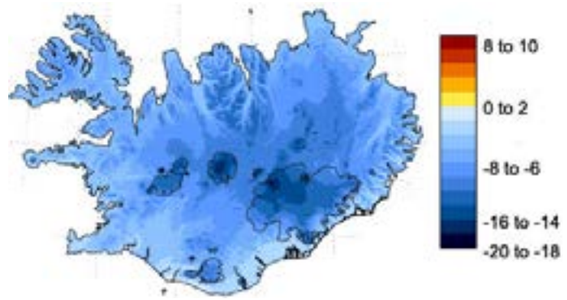
Strong winds occur frequently, especially during the winter. Road service is challenged by icing, snowfall and drifting snow, which due to sparse vegetation and absence of forest is acting on the whole road network. Snow avalanches threaten a few low-traffic volume roads in rural areas. Reduced bearing capacity and road damage during thaw periods in wintertime is a growing concern on old roads.

2.2 Statistics on temperatures, icing and precipitation

According to experience, snow is covering the ground during most of the mid-and late winter in areas where the mean temperature of the coldest month is below -4 °C. At the station of Reykjahlíð in the northeastern inland the snow is covering the ground completely for 135 days per year. In Reykjavík in the southwest this number is 55 on the average.

The temperature minimum drops below 0.0 °C on 123 days per year on the average in Reykjavík, 161 days in Akureyri in the north. These are typical lowland values.

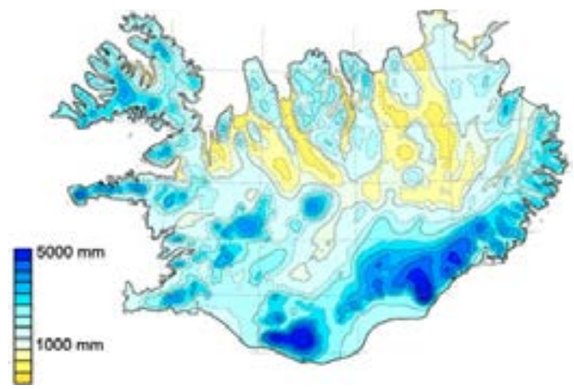
The north is on the average drier than the south, although significant exceptions can be found locally. Usually the precipitation is light. Reykjavík thus has some precipitation on 221 days per year, but on 148 of these the precipitation exceeds or equals 1mm. In Akureyri the corresponding numbers are 171 and 103.



MEAN MINIMUM JANUARY TEMPERATURE

Snow or sleet is recorded on 82 days per year in Reykjavík, but 96 in Akureyri. Freezing rain occurs, circa once per year, per location. Blowing snow is a significant traffic problem, especially outside the main towns.

The conditions outlined above are only valid for the lowlands. The winter problems increase considerably



MEAN ANNUAL PRECIPITATION

with height above sea level. In the vicinity of Reykavík the frequency of total snow cover days thus e.g., increases from 55 in Reykjavík (52m a.s.l.) to 91 at Stardalur (a few km to the East, at 185 m a.s.l.). Mean annual precipitation in Reykjavik for the period 1961-1990 is 800 mm, for Akureyri it is 490 mm and for Eyrarbakki on the south coast the mean annual precipitation is 1,370 mm.

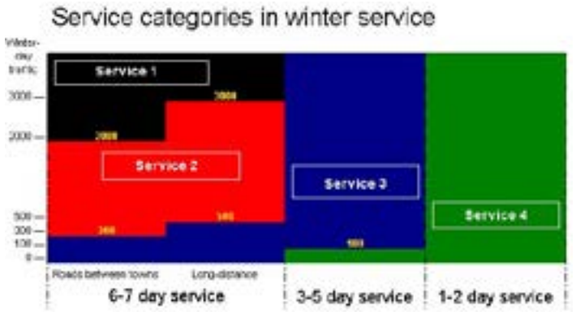
2.3 Winter index

A winter index was developed by ICERA for distributing winter budget between the different regions. The index reflects critical values and trends in temperature, humidity, and wind.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Snow and ice control, traffic information and winter road management is carried out by ICERA according to rules set by the Ministry of The Interior. Operation of the winter service is outsourced to private entrepreneurs. ICERA is financed by state budget and road-user taxes.



THERE ARE FOUR SERVICE CATEGORIES/CLASSES CONSIDERING ROAD FUNCTION AND TRAFFIC VOLUME.

Quality requirements for winter services concern the following factors:

- Service aims;
- Service level/category;
- Timing of actions;
- Maximum snow depth and road surface evenness criteria;
- Ice conditions/friction;
- Visibility at intersections and levelling of snow banks.

Besides the service class categorisation, roads in the lower service classes are subject to different number of service days pr. week.

Service class 1 implies a "bare road" strategy and relies on continuous use of de-icing chemicals, only NaCl is used. Pre-wet salt is the main application method.

Summary of the service requirements for roads in service categories 1 and 2 is as follows;

Service classes 2, 3 and 4 allow a certain amount of packet snow and ice with minimum friction criteria. Salt is used in these lower classes only when reasonable due to the weather conditions e.g. in autumn and spring.

3.2 Organization and operation of winter maintenance

Management and organisation

ICERA runs two control and surveillance centres that share the overall organisation of the winter service, and

Summary of Winter Service Quality Standards		Service Class 1	Service Class 2
Service hours	In town	24 / 7 service	06:00 - 22:30
	60 km from town		08:15 - 22:00
	120 km from town		10:30 - 21:30
Critical snow depth for service		2 cm	4 cm
After snowfall, ploughing		2 hours	3 hours
After road closure, snow removal is completed within		-	3 hours
Max. service cycle duration		2 hours	
Max. service route pr. vehicle		50 km	
Maximum snow depth		5 cm	12 cm
Maximum track depth		1 cm	2 cm
Min. friction coefficient	Generally	μ >0.25	μ >0.15
	Curves and slopes	μ >0.25	μ >0.25

monitor weather and road conditions on a 24/7 basis from October 15th until April 30th. Countrywide there are 18 regional service centres co-ordinating the force of contractors responsible for the operational tasks and the on-site road condition assessment are carried out by contractors.

In larger towns the ICERA is serving the major roads according to the ICERA standards based on contracts with the local municipal authorities.

The service equipment fleet is mainly trucks with snowploughs and salt spreaders, pay loaders and graders. Rotary blowers are very important in winter service on mountain roads and exposed primary roads. Grader works, such as removal of hard snow and ice are increasingly overtaken by plough-trucks with under-body blades. Graders are, however, still important to level snow banks on the road shoulder in exposed areas.

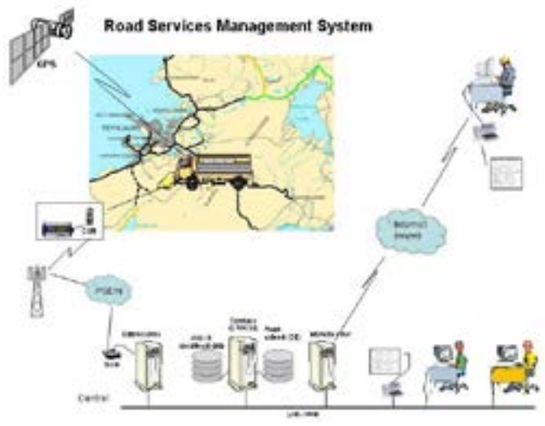
Depending on the service category, the service route per vehicle is 50-120 km. Usually there are 1 or 2 men per truck.

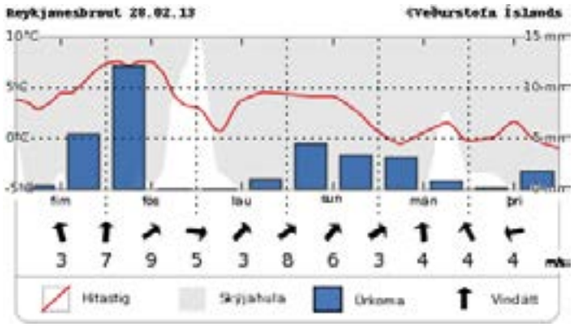
The ICERA´s internal codes define the responsibility for different tasks concerning winter services:

Unit	Tasks / Responsibility
ICERA Management Service Department	Overall service procurer Central planning and organisation Service standards and rules Assign service category to roads Operation of RWIS and other information systems Training and education
Control and Surveillance Centre 2 centres countrywide	Monitor weather and road conditions Planning and coordination Registration and information processing Service assessment
Regional Service Centre 18 centres countrywide	Inventory Daily operation management Control: - Road condition in-situ - Service quality - Budget
Contractors	Operational tasks - Snow ploughing - De-icing, sanding

Road closures are enforced by the police under adverse weather conditions according to the ICERA´s evaluation. Snow-Avalanche hazard, flooding, etc., may also lead to road closure.

Automatic vehicle location and activity registration is used for settlement of winter services and as well as for quality control. AVL equipment, consisting of a telecommunications device (GSM) and sensors, is installed in snow removal equipment with a salt and brine spreader as well as front and under-body blades to automatically collect information about location, activities, speed, distance and time. Upon receipt of data from a device, the grid position is plotted into the road system,





along with information on salt/sand use, length of road cleared, etc.

Road weather information

ICERA has contracts with the Icelandic Meteorological Office. In the current information system for the ICERA, data is gathered into a central database. Forecast period up to six days is used. There are approximately 100 road weather stations (approx. 100 RWIS stations countrywide). For 19 road stations, a six day forecast meteogram is issued (ilustration).

Operators in the two control centres monitor weather forecast and observations as well as the approximately 100 camera-points on the roads.

3.2 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

Cost & benefits of winter maintenance activities

The annual cost of the winter maintenance in 2011-2012 on the road network (excluding highland roads) is:

Road network open for winter service	10,472 km
Total winter service costs 2011-2012	1,200 EUR/km/year
Road network treated with salt, Σ(2-lane kilometres)	1854 km
Amount of salt used	27,600 t/year
14,9 t/km/year	2,3 kg/m2/year

The winter index mentioned in previous chapter turns out to reflect the actual annual cost reasonably well each winter.

Methods to decrease use of salt while maintaining the service levels

Through observations of water amount, residual salt and road surface temperature, and considering the weather outlook, salt dosage for concurrent actions is defined. The use of automatic sensors and manual measurements for this purpose is in a development phase.

3.3 Traffic safety and information

Information provision to the road user

Information is provided through various media. Information provided is; condition of road (slipperiness), weather (wind speed, gust and wind direction, temperature), road temperature, humidity and dew-point, traffic (last 10 minutes, traffic from midnight), estimated

time of opening if road is closed, maintenance works, axle-load restrictions, ferry schedules etc. The one hundred camera-points are available to the general public through internet.

Use of weather related road sensors and variable road signs

Most of the ICERA´s weather stations have temperature sensors in the road surface, and some have road surface humidity sensors for management use only. Frost depth sensors are used to determine weight restrictions on roads. Variable message signs are used to show wind speed, wind direction, temperature and in extremely exposed areas wind gust. Variable roads signs are also used to show if a road is closed.

Use of information technologies for efficient management and for avoidance of danger by providing information to road users

Information and warnings are provided through radio, internet, text-TV, phone service and message signs.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGY

ICERA is developing different models and instruments to enhance the availability of road weather information. Among the systems that have been developed and are under validation are;

Wind gust forecast, for chosen sites. The model utilizes historical statistics on the relationship between measured wind gust on road weather stations and the forecast for atmospheric conditions. The model indicates the probability of wind gust over a certain threshold for the particular site the next 28 hours.

Frost depth forecast, for freeze-thaw conditions in the road sub-base. The model takes readings from the frost depth monitoring system previously developed for ICERA, as an initial condition and extends the five day weather forecast through the road sub-base to indicate when axle load restrictions are necessary for the low-bearing capacity roads.

Road surface temperature and icing forecast is under development. The model gives accurate prognosis for road temperatures under the most critical conditions for sudden icing on the road network. This prognosis is important e.g. when road temperatures drop below the freezing point due to long wave emission from the

surface due clear sky, even when air temperatures are still significantly above the freezing point.

Residual salt and ice detection sensor has been developed. The sensor indicates the road surface temperature, the freezing of liquid present on the surface and gives estimate on the residual salt left on the pavement surface.

Customizing salt dosage. A new procedure for defining dosage for salt spreading is under trial at the control and surveillance centre for the capital area. The aim is to use available information on road condition, including residual salt, weather and traffic pattern to define the salt dosage. The goal is to use less salt without compromising service quality.

Modelling Residual Salt (MORS-project). ICERA participates in the NordFoU MORS project. The aim is to develop a model which is capable of predicting the residual salt development on the road, taking traffic, road and weather parameters into consideration.

4.2 NEW MANAGEMENT AND ORGANIZATION APPROACHES

The hierarchy describes in chapter 3.2 describes a new organisational approach adopted by ICERA in 2012. The new structure facilitates a more centralized management in order to harmonize practise in the regions and enable a more flexible use of the workforce without administrative boundaries. Centralizing surveillance and call-out has economic benefits and is believed to be more reliable.

Training. Since autumn 2012, it is decided that all staff engaged in winter management and operations shall undergo a training course.

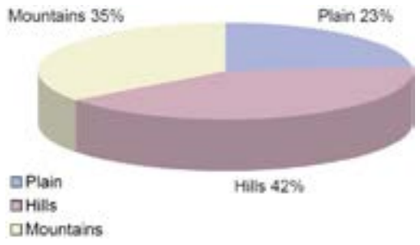
5 REFERENCES

Traffic and weather information in English on ICERA's internet site:
http://www.vegagerdin.is/english/
Statistics Iceland: http://www.statice.is/
The Road Traffic Directorate:
http://www.us.is/umferdarstofa/english

1. DEMOGRAPHICS AND ROADS

Area	301,302 km²	
Population	60 millions	
Length of roads	National roads and highways	31,000 km
	Prefecture roads	141,000 km
	Municipal roads	300,000 km
Latitude (capital)		41°53'N

Country and Road statistics

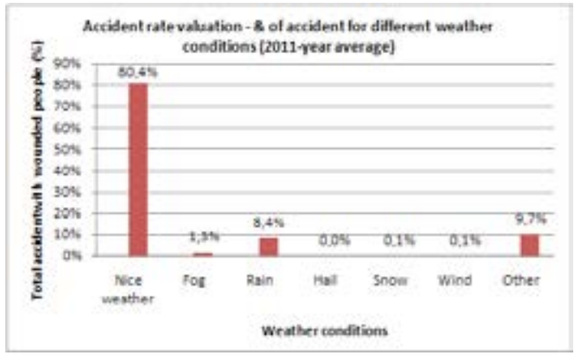


	Plain	Hills	Mountains	Total
Area (km²)	69,902	125,342	106,058	301,302
%	23.2	41.6	35.2	100,0

Orography

2. CLIMATE

Temperature and precipitations statistics		Alt.	Monthly mean temperature (5-year average) (°C)				Daily minimum temperature (5-year average) (C°)				Snowfall (4-year average)	Precipitation (5-year average)
		(m)	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar	days	mm.
Lombardia (North)	Milano	107	3,6	3,4	4,7	9,3	-4,0	-4,9	-3,2	0,3	3	720
	Monte Bisbino	1.319	2,4	1,3	1,2	3,6	-2,7	-5,3	-7,7	-3,8	21	1363
Lazio (Centre)	Roma	18	9,1	7,4	7,9	9,5	-1,5	-2,1	-2,2	-0,1	1	490
	Monte Terminillo	1.874	-0,1	-0,1	-2,1	0,5	-7,7	-8,3	-10,9	-9,4	7	1045
Calabria (South)	Reggio Calabria	11	13,1	13,4	11,9	13,4	5,9	6,4	5,7	6,9	1	341
	Monte Scuro	1.710	0,5	-0,2	-1,3	1,1	-7,3	-6,9	-7,9	-7,4	4	841
Sardegna (Islands)	Cagliari	4	11,0	10,3	9,8	11,9	3,8	1,5	2,3	3,6	1	378
	Fonni	1.022	6,8	6,5	5,8	6,5	0,8	-2,5	0,5	-0,4	5	808



Accident rate valuation - % of accident for different weather conditions (2011-year average)	
Nice weather	80%
Fog	1,3%
Rain	8,4%
Hail	0,0%
Snow	0,1%
Wind	0,1
Other	9,7

Annual road accidents / weather conditions (2011-years average)

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

The Ministry of Intrastructure and Transports established the minimum standards and rules for snow and frost removal service on state road and motorways.

AIMS

The main aim of Winter road management is to keep road users on the move and/or to rapidly re-open to traffic in winter when traffic must be discontinued. This is to be achieved also by means of very urgent interventions along the managed road and motorway network subject to snow falls and frost.

Description

Winter road management embraces the following activities:

Snow removal: it includes the removal of the layers of snow, mud, ice from the pavement, from the verges of the carriageways endowed with New Jersey or guard-rails, from bridges and viaducts and tunnels (entrance-exit portals)

De-icing treatment: it consists in spreading, beforehand, de-icing salts on roads and/or anti-icing mixtures (salts and aggregates) in order to prevent ice formation on pavements, on bridges and viaducts, near tunnels (entrance/exit portals)

Emergency assistance: it consists in snow removal and anti-icing treatment by means of ad hoc teams operating for urgent interventions to be carried out (upon a call)

Felling of dangerous trees and removal of the discarded material;

Removal of the trees damaged by snow showers by the cutting of branches at the slinging and subesequently cutting them to pieces

Service supply

The Departmental Offices provides for a constant planning of such activities according to the weather and altimetric characteristics of the relevant areas.

The availability of men and means to tackle sudden emergency and/or unforeseeable situations is guaranteed apart from bad weather conditions (snow falls and/or frost) and considering the need of keeping a high standard level of service, while reducing the risks on the managed road and motorway networks.

All these activities are carried out by means of trained teams equipped with mechanic means, snow blowers, snow blowers and cutters , salt spreaders.

The foreseen activities are normally carried out continuously for a 6 month period (November-April) all day long and in working days and holidays.

All such activities are carried out in such a way to provoque the least traffic congestion possible. Furthermore they are all carried out by means of ad hoc signals and barriers

Supply times

The above activities are generally implemented according to the following scheme:

Snow removal and anti-ice treatment, according to the frequency of snow falls and frost formation for a period of 4 up to 6 months,following the orographic characteristics of the network;

Emergency activation: upon call (ANAS monitoring personnel, police etc) due to emergency situations, ge-

nerally within 60 minutes from the call all day long in working days and holidays).

PERFORMANCE INDICATORS AND RELEVANT INDICATORS RELATED TO ROAD AND MOTORWAYS SERVICE

Performance indicators related to the national roads network:

Snow removal index

$$I_{SN} = 2 - \frac{SN_{cons}}{SN_{rif}}$$

Snow removal indicator (Isn) is a ratio between performance in snow removal (SN cons), measured in number of roads closed for traffic over than 12 hours, without exceptional cases, and the expected maximum value.

Where:

SN cons = (SN cons1 + SN cons2 +…..+ SN cons n)
(Total traffic closing over 12 hours)

SN rif = allowed maximum value number of roads closed for traffic over than 12 hours, without exceptional cases.

Exceptional are scheduled roads closing (e.g. crossing place in mountains) or during exceptional snow falls (more than last 5 years average).

Indicator	*Incidence*
Moving Grass I_{SE}	20%
Clear Snow I_{SN}	10%
Markings I_{SO}	20%
Reconditioning operations Technological Systems I_{IL}	10%
Reconditioning operations flooring emergency I_{PAV}	20%
Informobility I_{IM}	20%

Synthetic index

Same index as well as for snow removal there are for Grass cutting (I se), Orizontal road signs (I so), Tecnological plants work-service (I il), roads paving emergency work-service (I pav), traffic informations (I im) too.

To each specific indicator is associated with a decimal weighting factor to take into account the different size of the reference measurements associated with each of them.

In this way Synthetic index is calculate and the formula is:

I = (0,2* ISE + 0,1* ISN + 0,2* ISO + 0,1* IIL + 0,2* IPAV +0,2 * IIM)

A lower value of the unit may lead to the application of a penalty under the following terms:

Penalty	Value indicator	Scope of the penal annual value of resources acquired pursuant to art. 19, paragraph 9-bis of Law 102/2009 and subsequent amendments and the intended operating activities
Nothing	$0,95 = I < 1$	0
Minimum	$0,9 = I < 0,95$	0,01% up to a maximum of € 100,000
Middle	$0,8 < I < 0,9$	0,02% up to a maximum of € 50,000
Maximum	$I < 0,8$	0,03% up to a maximum of € 200,000

Roads under inspection

The calculation of the indicators for measuring the performance of Anas in the performance of activities subject to inspection will be carried out on a sample of roads assigned under management.

The choice of roads must be guided by the use of appropriate selection parameters that allow to identify a significant sample.

The selection of the roads then may be made taking into account the following parameters:

- Type of road (highway, junction, highway);
- Traffic volumes;
- Strategic importance of the road;
- Geographical distribution throughout the country.

3.2. METEOROLOGICAL INFORMATION AND FORECAST

Meteorological information and forecast are provided by Italian Air Force (Aeronautica Militare Italiana) which sees to the collection, processing of data and meteorological products (analyses, forecasts, advice and so on) all over the national territory.

3.3. TRAFFIC SAFETY AND INFORMATION

Meteorological and traffic information to users broadcasted by radio are processed and spread by the information centre CIIS by means of the following national networks:

RTL (102.5 MF) updated every 30 mts between 06.30 and 21.00

RADIO RAI : updated maximum every 30 mts

ISORADIO: (103 Mhz): every 30 mts covering the motorway network

The information Centre CIIS was created in 1990 on the initiative of the Ministry of Infrastructure and Transports (the then Ministry of Public Works) and of the Interiors Ministry, as and information means for road safety regulated by law n.556 of 30.12.1998 and subsequent rugulations.

This service is carried out in co-operation with ACI, ANAS S.p.A., Autostrade per l'Italia S.p.A., Arma dei Carabinieri, Polizia Stradale, RAI and Polizia Municipale in Rome

3.4. ORGANIZATION AND OPERATIONS FOR WINTER MAINTENANCE

With regards to winter climatic conditions, Italy has very different features along the territory. The northern borders of the Italy territory flank countries with old seasons longer than its own, whilst the south is characterized by a long hot and sunny season. Mountains are in all the Italian regions and so the territory and climate are variegated everywhere. Only 23% of the Italian territory is on a plain. The Alps cross all the Italian northern regions with Mount Blanc at 4,810 m as the highest mountain. The Apennine mountain chain runs north to south. Here many mountains are over 2,000 m with the Gran Sasso reaching 2,914 m. On the two bigger Italian islands too there are tall mountains such as Etna (3,340 m) in Sicily and Gennargentu (1,834 m) in Sardinia.

These features give a big variety in climate and in microclimate so special attention must be given to the possibility of snowfall as well as where it appears unlikely in regions located in the southern latitude and near the sea. The snow is different in the northern regions, where it is dry and light, compared with, wet and heavy snow in the southern regions.

ANAS (the Italian Agency for National Road construction and management), highway management organizations, local autority and municipality offices carry out winter maintenance with their own equipment and with the assistance of private firms to ensure safety for road users in winter.

3.5. METEOROLOGICAL INFORMATION AND FORECAST

Meteorological information and forecast are provided by Italian Air Force (Aeronautica Militare Italiana) which sees to the collection, processing of data and meteorological products (analyses, forecasts, advice and so on) all over the national territory.

The surveys are carried out by satellites and by a strict network of meteorological stations along the national territory.

3.6. TRAFFIC SAFETY AND INFORMATION

Meteorological and traffic information to users broadcasted by radio are processed and spread by the information centre CIIS by means of the following national networks:

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This service is carried out in co-operation with ACI, ANAS S.p.A., Autostrade per l'Italia S.p.A., Arma dei Carabinieri, Polizia Stradale, RAI and Polizia Municipale in Rome

4. REFERENCES

ISTAT – Statistiche Meteorologiche
www. istat.it
ANAS – Carta dei Servizi Stradali e Autostradali
www.radio.rai.it
ww.autostrade.it
www.meteoam.it
ANAS- Fog alert project
www.stradeanas.it

1 DEMOGRAPHICS AND ROADS

FIGURE 1 - LOCATION OF JAPAN

Some of the urban areas of Japan receive much more snowfall than urban areas anywhere else in the world. In the cold, snowy regions of Japan, when it snows, traffic is often paralyzed. Roads are damaged by freezing in extremely cold regions.

To ensure the safe, reliable flow of road traffic in severely cold, snowy regions of the country, The Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas was enacted in April 1956. Cold, snowy districts account for nearly 60% of Japan's land area, some 40% of its municipalities, and about 20% its population (Figure 2).

Table 1 - Area, population and roads in Japan

Area	377,971 km²	
Population	127,095 mil. people	
Length of Road	National expressway	8,652 km
	National highway	55,645 km
	Prefectural road	129,446 km
	Municipal road	1,026,980 km
Latitude (capital)	35º N. Lat. (Tokyo)	

Source: Population: Ministry of Internal Affairs and Communications Statistics Bureau website (FY 2015); Annual Report of Road Statistics 2016, Ministry of Land, Infrastructure, Transport and Tourism

FIGURE 2 - OVERVIEW OF CLIMATIC AREAS

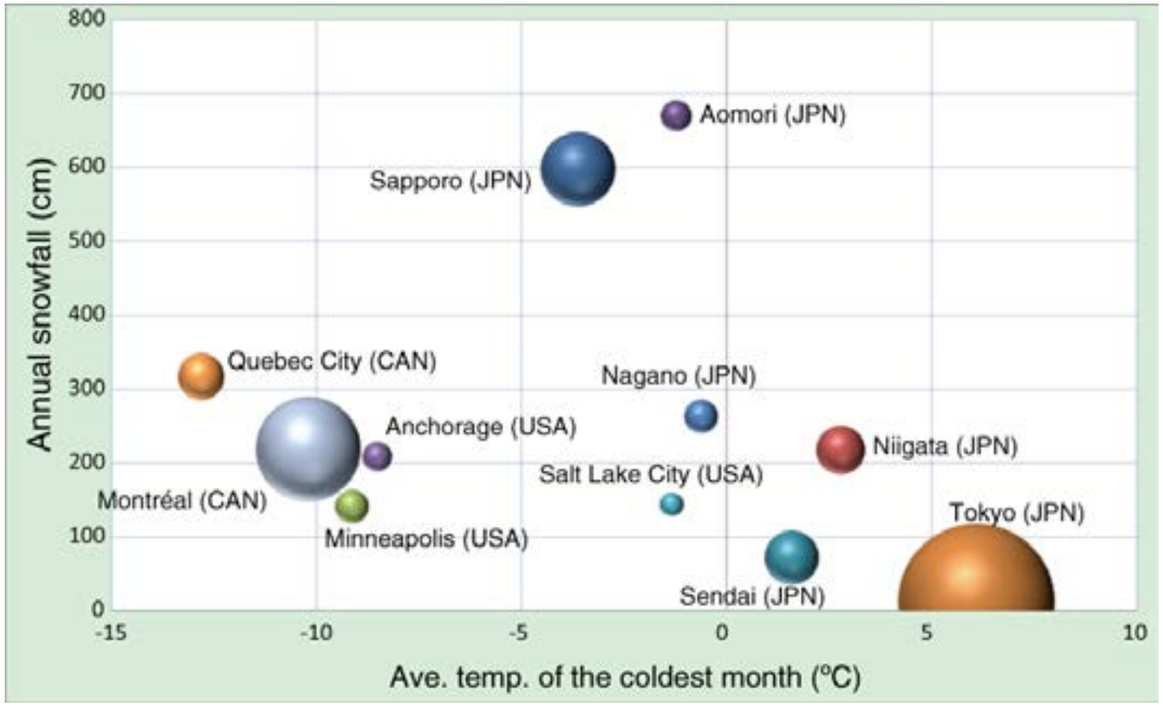


FIGURE 3 - AIR TEMPERATURE OF THE COLDEST MONTH, AND ANNUAL SNOWFALL

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

Japan is more southerly than most other cold, snowy countries. Even so, most of the country receives snowfall, expect for the southern part of Kyushu Island. The areas indicated as cold and snowy on the map (Figure 2) are those designated as such by the Law. The climate in these areas is much colder than elsewhere in Japan. Temperatures drops far below freezing, and winters see extreme snowfall. As shown on the map, snow falls heavily in the northern Japan Sea coastal area (Hokuriku Region). This is one of the features of winter in Japan.

The heavy snowfall on the Japan Sea side occurs when cold air from Siberia absorbs great amounts of moisture over the Japan Sea and then meets the high mountains that make up the northeast-by-southwest backbone of northeastern Honshu Island. The rising air cools, forming snow clouds.

Many Japanese cities are among the snowiest in the world. More than two million people live in and around Sapporo, the capital of Hokkaido, despite an annual snowfall of nearly 6 m. It is the only city in the world where such a great number of people live amidst such extreme snowfall.

Source: United Nations Demographic Yearbook; Japan Meteorological Agency

Note: The size of the globe indicates the population of the city.

2.2 Statistics on Temperature, Snowfall and Precipitation

Table 2 - Temperature and precipitation (30-year avg., 1981 - 2010)

	Daily min. temperature [°C]				Snowfall [cm]			Precipitation [mm]				
	Dec.	Jan.	Feb.	Mar.	Daily maximum snowfall	Maximum snow depth	Cumulative snowfall	Dec.	Jan.	Feb.	Mar.	Total
Sapporo	-4.1	-7.0	-6.6	-2.9	37	100	597	111.7	113.6	94.0	77.8	1106.5
Aomori	-1.4	-3.9	-3.7	-1.3	34	111	669	150.8	144.9	111.0	69.9	1300.1
Sendai	0.9	-1.7	-1.5	0.9	15	17	71	36.6	37.0	38.4	68.2	1254.1
Niigata	2.7	0.2	0.1	2.3	24	36	217	217.4	186.0	122.4	112.6	1821.0
Tokyo	5.1	2.5	2.9	5.8	5	6	11	51.0	52.3	56.1	117.5	1528.8
Nagano	-1.6	-4.1	-3.8	-0.8	22	31	263	45.5	51.1	49.8	59.4	932.7

Source: Japan Meteorological Agency

Roads in regions designated as cold/snowy under the Law and that meet the traffic volume criteria set by the Minister of Land, Infrastructure, Transport and Tourism are designated as roads subject to the Law. Securing of traffic on such roads is especially important for the promotion of socioeconomic activities.

FIGURE 4 - OUTLINE OF THE SPECIAL MEASURES LAW FOR ENSURING ROAD TRAFFIC IN SNOWY AND COLD AREAS

3 WINTER ROAD MANAGEMENT

3.1 HISTORY AND BACKGROUND OF SNOW- AND ICE-CONTROL PROGRAMS

In 1956, The Special Measures Law for Ensuring Road Traffic in Snowy and Cold Areas was enacted. Snow- and ice-control programs were established to ensure smooth winter traffic that supports winter living in cold, snowy regions, because snowfall causes road closures and traffic accidents including skidding accidents on icy roads, and the roads are damaged by frost heave in such regions. The Law was legislated to reduce local governments' mounting financial burdens and to provide measures against these hindrances amidst a rapid increase in vehicle ownership.

The need for measures against the extremely slippery roads that have emerged since studded tires were banned has been an issue. Such roads have caused increases in vehicle skidding and pedestrian fall accidents.

3.2 LEVEL OF SERVICES (LOS)

Criteria for the deployment of snow- and ice- control staff and vehicles and winter road LOS are set for each road category according to the snowfall, air temperature and traffic volume in each cold, snowy region. Winter management, including the plowing of newly fallen snow, the application of anti-freezing agents and of snow hauling, is based on such criteria and on LOS.

The Hokuriku Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism sets deployment criteria for each type of winter maintenance operation (Table 3). The City of Sapporo sets LOS (Table 4) by road type.

Table 3 - Criteria for deploying snow- and ice-control operations

Example on national highways in the Hokuriku Region

Operation		Deployment criteria
Patrol		1. Monitor snowfall and freezing forecasts, and dispatch patrols as necessary. 2. Dispatch additional patrols as necessary, especially when... 1) Snow/ice-related traffic disruption is anticipated. 2) Traffic disruption is reported by police, road condition monitors, other road users or local residents.
Snow removal	Plowing	There is 5 to 10 cm of snow on the road, and further snowfall is expected.
	Surface leveling	1. The great amount of snow on roads is anticipated to cause traffic disruption unless it is leveled. 2. This is done to prevent the compacted snow layer from thickening and to eliminate unevenness.
	Compacted snow and ice scraping	Due to temperature fluctuations and the load of passing vehicles, compacted snow has become uneven enough to disrupt traffic.
Widening effective road widths with rotary blower		1. Heavy snowfall has prompted the need for plowing to secure the effective road width. 2. Snowbanks at the shoulder have become so large that they are expected to disrupt traffic when wind moves the snow.
Hauling		Roadside snowbanks have become so large that they hinder vehicles passing each other in opposite directions, and further snowfall is forecast. Or snow removed from roofs of houses along the road is expected to enlarge the snowbanks.
Sidewalk snow removal		At the instruction of a supervisor
Salting		Road icing is forecast or has been reported.
Operation of snow-melting facilities		1. Snow has fallen. 2. Icy roads have been reported (road heating operation is necessary).
Other operations		At the instruction of a supervising personnel

FIGURE 5 - MULTI-LANE SNOW REMOVAL

(Sidewalks)

Road type	Criteria	LOS	Criteria for securing road width
Side-walk	2 m < Effective width	Maintain the surface so that walking on the sidewalk is not hindered	Length of the blade of sidewalk snow remover (1.3 - 1.5 m); enough width for pedestrians to pass by each other

FIGURE 6 - SIDEWALK SNOW REMOVAL

TABLE 4 - WINTER ROAD SERVICE LEVEL BY ROAD TYPE IN THE CITY OF SAPPORO

Road type	Roles of the road	Typical road structure	Depth of compressed snow layer	Criteria for securing road width
Major arterial	Linking cities and major destinations within the city	6-lane road	Within 3 cm (no rutting formed)	4 lanes or more (about 13 m); enough width so that right/left turning vehicles do not interfere with other vehicles
Arterial	Collecting traffic between major destinations in the city/major facilities;	forming frameworks of residential areas	4-lane road Within 5 cm (no rutting formed)	3 lanes or more (about 9 m); enough width so that right-turning vehicles do not interfere with other vehicles
Secondary	Collecting traffic in residential areas and directing it to arterial roads; providing links between rural roads and arterial roads, and access to major facilities within the residential area	2-lane road	Within 25 cm (no driving interference)	1 1/2 lanes or more (about 4 m); enough width for small automobiles to pass by each other
Tertiary / rural	Access to/from dwellings	8 m ≤ road width < 10 m	Within 30 cm	1 lane and pedestrian space (about 3.2 m); enough width for an emergency vehicle to drive through

FIGURE 7 - APPLICATION OF ANTI-FREEZING AGENTS

3.3 SNOW- AND ICE-CONTROL MEASURES

Snow removal

Snow removal on roadways

To maintain the trafficability of national highways and principal prefectural roads and to promote interregional exchanges and living activities, snow removal on roadways is conducted around the clock.

Snow removal on sidewalks

Snow removal on sidewalks is promoted around schools, railway stations, downtown and social welfare facilities, to ensure the safety and reliability of walking spaces in winter.

Application of anti-freezing agents

Since the ban on studded tires, extremely slippery road surfaces frequently have emerged in winter. Anti-freezing agents are efficiently applied to reduce traffic congestion and slip accidents.

Snow-control measures

Various facilities are constructed as countermeasures to avalanche and snowstorm.

AVALANCHE CONTROL FENCE SNOW SHED

FIGURE 8 - SNOW-CONTROL FACILITIES

Snowbreak woods

These catch snow particles carried by winds and hold them in snowdrifts within the woods or on their windward side to prevent snow from blowing onto roads on the downwind side.

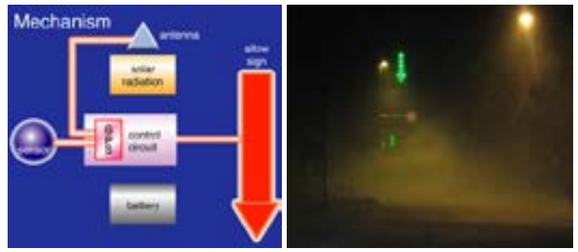


FIGURE 9 - LIGHT-EMITTING DELINEATOR: DIAGRAM AND ONSITE INSTALLATION

Snowfences

These keep snow from blowing into drifts on the road, and they mitigate height increases of roadside snowbanks with snow plowed from the roadway, thus improving visibility of the road.

Avalanche control fences

These are constructed on avalanche-prone roadside slopes.

SNOWBREAK WOODS

SNOWFENCE

WITHOUT ROAD HEATING WITH ROAD HEATING

FIGURE 10 - EFFECT OF ROAD HEATING SYSTEM

FIGURE 11 - EFFECT OF SNOW-MELTING SPRINKLER
SNOW-FLOWING GUTTER

Snow sheds

These are constructed over roads so that avalanches will pass over them without endangering the safety of the roads.

Light-emitting delineators

The delineators, which run on eco-friendly solar energy, are easily recognized, and they improve the efficiency of snow removal.

- **Snow-Melting Facilities**

Road heating

Road heating systems melt snow or prevent road icing by heating the pavement using heating pipes or electric coils, rather than by sprinkling the road with water.

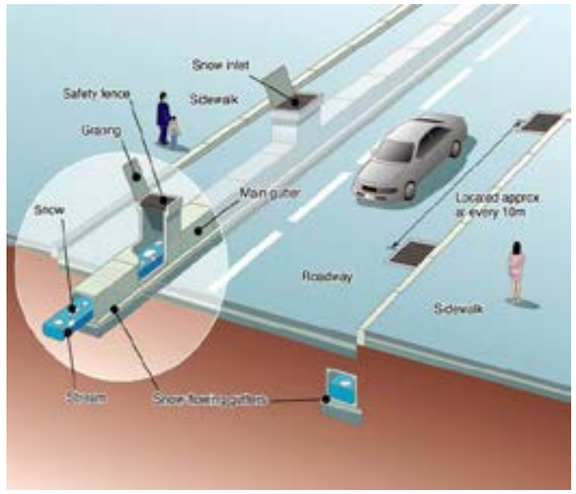


FIGURE 12 - DIAGRAM OF SNOW-FLOWING GUTTER

RESIDENTS DUMPING SNOW INTO THE SNOW-FLOWING GUTTER

MAINTAINING THE SAME EFFECTIVE ROAD WIDTH IN SUMMER AND WINTER

FIGURE 13 - EFFECT OF SNOW-FLOWING GUTTER

HEAT SOURCE OF SNOW-MELTING TANK: WARM PROCESSED SEWAGE, RESIDUAL HEAT FROM INCINERATION PLANTS, ETC.

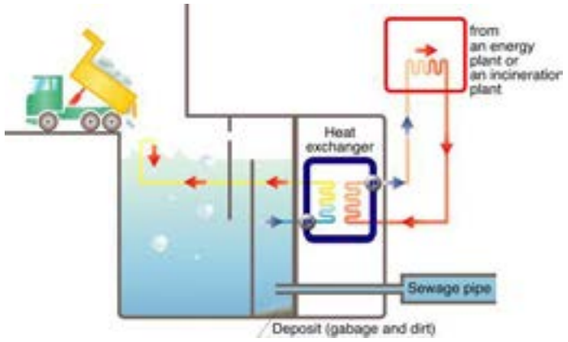


FIGURE 14 - SNOW-MELTING TANK

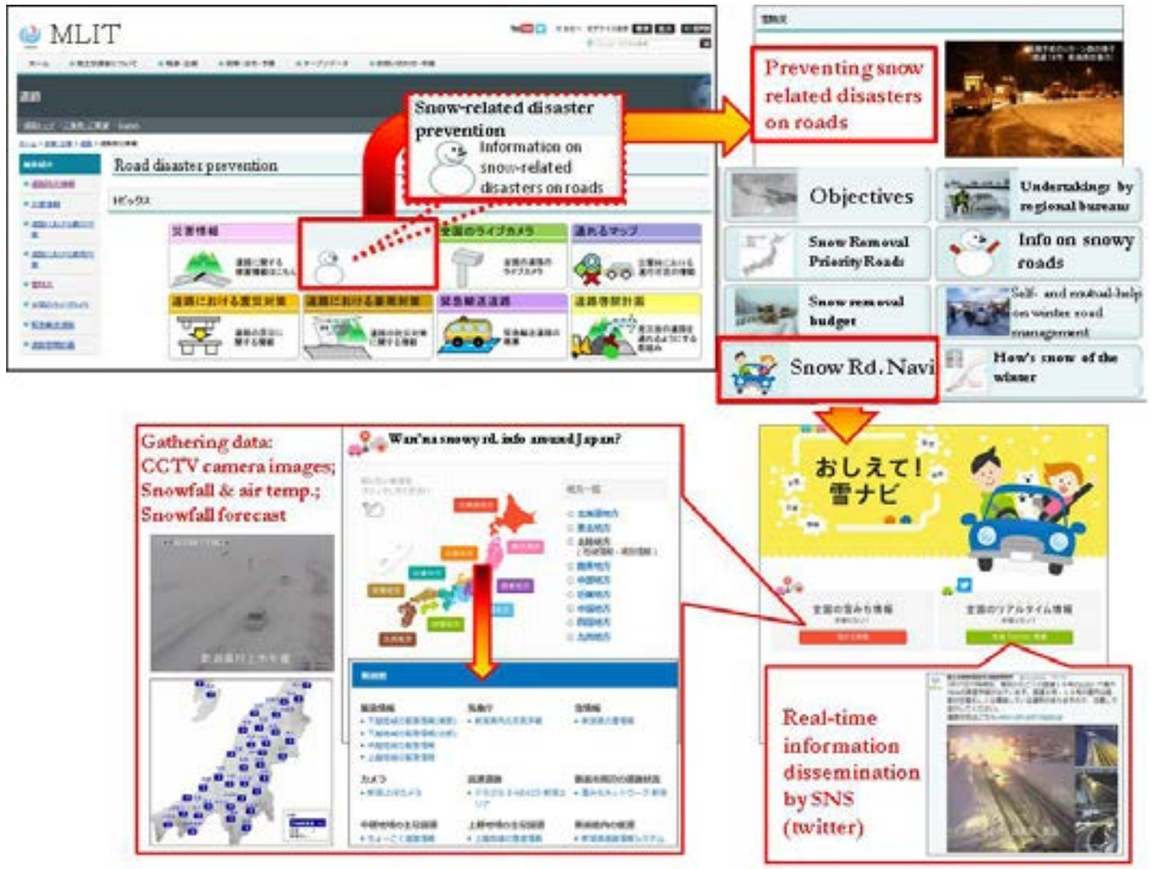


FIGURE 15 - WEBSITE FOR WINTER ROAD INFORMATION

FIGURE 16 - WEBSITE SHOWING PRIORITY ROAD SECTIONS FOR SNOW REMOVAL

Snow-melting sprinkler

Groundwater is pumped up and sent through pipes for sprinkling from nozzles to melt snow. The pipes and nozzles are embedded in the road.

The City of Sapporo has constructed eight snow-flowing gutters to dispose of snow with the cooperation of local residents. These gutters are constructed at the roadside. Residents dump snow on the street into the openings of a covered box culvert, where snow is swept away by water running down a natural incline. In general, the water source is river water. However, at seven gutters out of the eight snow-flowing gutters, Sapporo also uses processed sewage effluent at 10°C from sewage-treatment plants.

The use of processed sewage water has the advantage of requiring less discharge capacity than in the case of using river water, because the higher temperature of sewer water reduces the snow volume by melting the snow.

FIGURE 17 - INFORMATION PROVIDED ON A SOCIAL NETWORKING SITE AT THE TIME OF HEAVY SNOW

Snow-melting tank

Snow-melting tanks melt large quantities of snow while occupying relatively small areas of land. Such tanks dispose of snow that is removed from roads, carried by dump trucks and dumped directly into heated water. The energy used to melt snow is from sources previously considered as waste. These sources include 1) heat of processed sewage effluent, and 2) residual heat from district heating and cooling plants. The tanks are used not only during winter, but also during other seasons, as fire-fighting water tanks and balancing reservoirs to retain rainfall and sewage.

3.4 TRAFFIC SAFETY & INFORMATION

Winter road information provision

The Road Bureau and the Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) have been running a portal website for the purpose of providing detailed road information based on the situation in each area. The portal website contains links to regional road information websites and MLIT's website (Figure 15).

These websites provides information that is useful to drivers traveling on snow-covered roads, including webcam images, current temperatures and snowfall, and snowfall predictions. Regarding national highways and expressways, steep uphill road sections where large vehicles are likely to get stuck in the snow due to heavy snowfall are identified, and information about these road sections is posted on a relevant website. Road

FIGURE 18 - PORTAL WEBSITE OF SNOWSTORM VISIBILITY INFORMATION

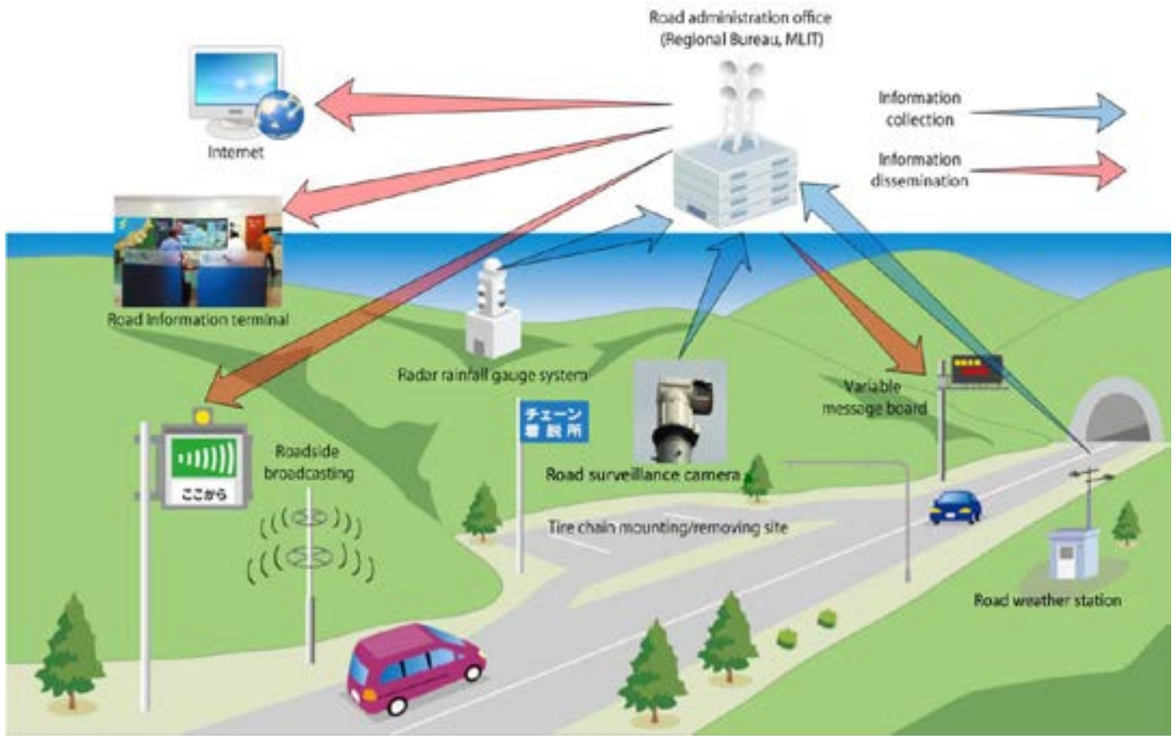
users are informed that snow is to be removed intensively and efficiently from these road sections (Figure 16).

At the time of heavy snow, Fukui Office of Rivers and National Highways provides information about congestion on roads and weather conditions on Twitter at fixed intervals (Figure 17).

The Civil Engineering Research Institute for Cold Region (CERI) has been conducting an experiment in which information about snowstorms is provided to drivers to help them to make decisions regarding traveling during a heavy snow storm. This experiment is part of CERI's research on the measures for preventing and mitigating disasters caused by snowstorms (Figure 18).

Road weather information system

National Highway 17 is a major arterial highway connecting the Tokyo metropolitan area and Niigata, the largest city in the Hokuriku Region of northwestern Hon-



ROAD WEATHER STATION

SNOW GAUGE AND THERMOMETER

ROAD SURVEILLANCE CAMERA

ICE SENSOR

MANAGEMENT USING REAL-TIME IMAGES

ROAD INFORMATION DISPLAYS

VARIABLE MESSAGE BOARD

(Left: home; right: enlarged map). Home displays all of Hokkaido Region. When an area and a forecast item (weather or road icing) are selected, the system displays a map with the selected information on any scale.
FIGURE 20 - WINTER MAINTENANCE SUPPORT SYSTEM

shu. The highway passes through areas of severe meteorological and topographic conditions. The 25 km of this highway between the Mikuni and Kandatsu areas, on the border between Niigata Prefecture and Gunma Prefecture, run through one of the snowiest areas in Japan. The geography of part of the highway is complex: There are seven sharp curves, with radii of 50 m or less, and there are 14.4 km of steep sections, with gradients of 4% or more. Because the section is designated as a pilot area due to its harsh winter conditions, the Ministry has implemented advanced snow- and ice-control measures.

Winter Maintenance Support System

CERI has developed the Winter Maintenance Support System to support winter maintenance against slippery, icy winter roads, including de-icing prior to the emergence of such road conditions. The system provides weather and road icing forecasts to road administrators and managers (Figure 20).

Top: Winter road friction provision system display Left bottom: Test vehicle with a continuous skid-resistance measurement device. Right bottom: Enlarged route map showing measured skid resistance
FIGURE 21 - WEBSITE OF WINTER ROAD CONDITION MONITORING DATA

4 ON GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

Website of winter road friction monitoring data

The road surface condition in winter varies by time and location. To quantitatively evaluate the road surface condition, CERI has been developing a system that monitors the road surface friction continuously by a vehicle in motion and that distributes the monitored results

Intelligent Salting Control Optimization System (ISCOS)

East Nippon Expressway Company Limited (MEXCO East Japan) has been using sodium chloride (i.e., pre-wetted salt) as an anti-freezing agent that helps to prevent road icing and to ensure winter traffic safety. In order to minimize damage caused by sodium chloride to expressway structures and also to enhance efficiency of winter maintenance operation with reduced costs, MEXCO East Japan developed Intelligent Salting Control Optimization System (ISCOS). This is the world's first system that automatically spreads an optimum amount of salt. Salting control is optimized by utilizing road surface data from Contact Area Information Sensing (CAIS) developed by Bridgestone Corporation. ISCOS has been used on expressways in Hokkaido (Figure 22).

Alternatives to sodium chloride

With an aim to prolong service life of expressway structures for reducing their life-cycle costs, Central Nippon Expressway Company Limited (NEXCO Central Japan) has been collaborating with Toyama Prefectural University and CERI in analyzing the applicability of new anti-freezing agents that can be used instead of sodium chloride.

Promotion of measures for barrier-free winter mobility

Comprehensive snow-removal measures have been formulated and implemented to remove barriers to wintertime mobility, such as the increased danger of pedestrian slip and fall accidents on icy roads, reduction of walking space due to snowfall, and other inconveniences.

Toward barrier-free mobility, thorough snow removal on sidewalks around railway stations has been promoted and road heating has been installed.

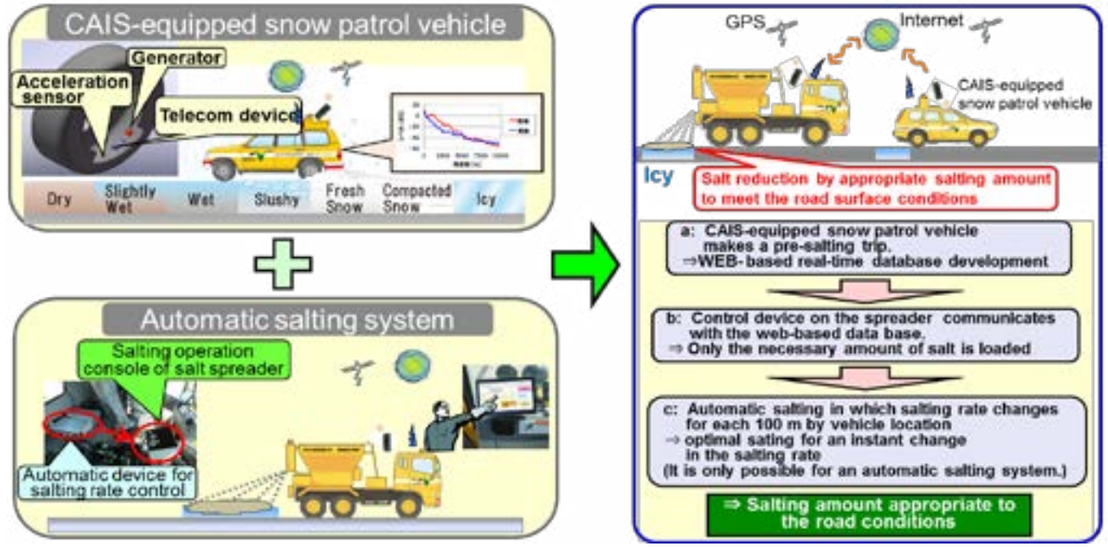


FIGURE 22 - INTELLIGENT SALTING CONTROL OPTIMIZATION SYSTEM (ISCOS)

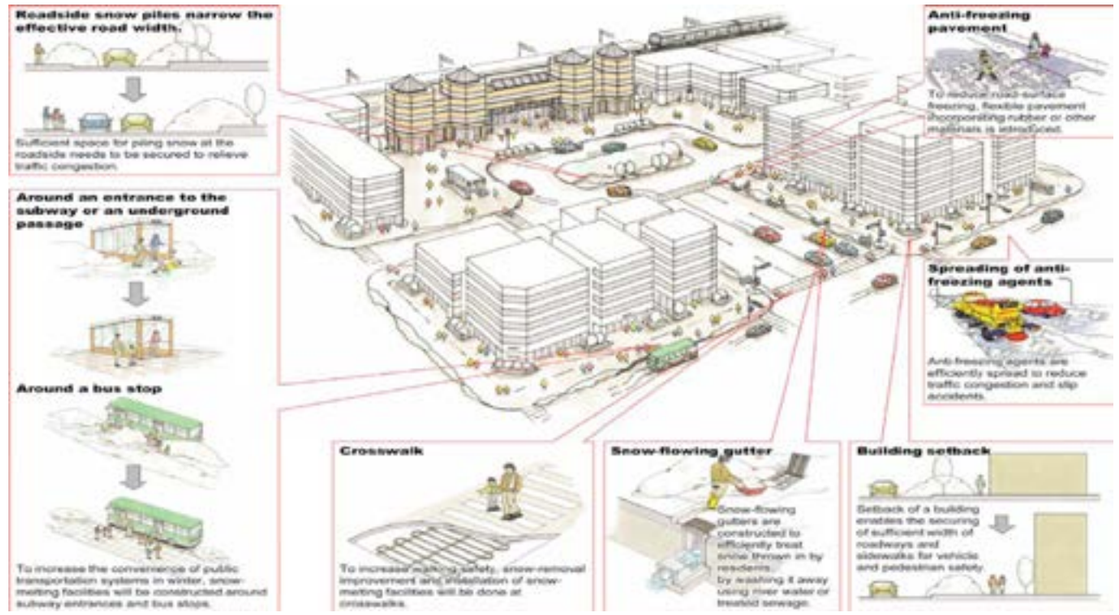


FIGURE 23 - MEASURES FOR BARRIER-FREE WINTER MOBILITY TAKEN IN CONJUNCTION WITH VARIOUS OTHER PROJECTS FOR SNOW- AND ICE-CONTROL

5 REFERENCES

Website of the Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism at
http://www.mlit.go.jp/road/

1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

Latvia is in north-eastern Europe, on the east coast of the Baltic Sea. It borders with Estonia, Lithuania, Russia and Belarus. Most of the Latvia's territory is little higher than 100 metres above sea level and ground cover is formed by sedimentary soils. The highest point is Gaizinkalns, 312 metres. There are thousands of rivers and lakes in Latvia, and about 8 % of inland territory is covered by swamps. Approximately one third of population of Latvia (697 thousand) lives in the capital Riga. In 2016 the unemployment rate was 9.6 %.

1.2. ROAD NETWORK AND TRAFFIC

Area	64,589 km²	
Population	2.0 million	
Density of population	30.8 pers/km²	
Total road and street length	State roads	20,081 km
	Municipal roads	38,149 km
	Forest roads	11,693 km
	Total	69,923 km
Latitude (Capital)	57⁰ N Riga	

The total length of paved roads is 14,605 km. The average density of roads is 0.92 km per km².

In 2015 average daily motor vehicle intensity on state main roads was 5,405 vehicles, including 1,112 (20.5 %) trucks.

2. CLIMATE

2.1. OVERVIEW OF THE CLIMATIC ZONE

Latvia's climate is influenced by the Baltic Sea. It is a moderate oceanic climate with pronounced cyclone activity that influences changes in weather 190 - 200 days a year. The western part of Latvia is characterized by maritime climate with milder winters and considerable temperature variations; in the east the climate is more continental. Winter in Latvia usually lasts from the second part of November till the end of March. It starts gradually, usually moderate frost, clouded days, lots of snow and sometimes rain. In recent years, climate changes can be observed here as a higher probability of certain extreme meteorological events (precipitations, temperature peaks) from their long-term statistic level.

2.2. STATISTICS

The average temperature in January in coastal regions is -2 0 C, in eastern parts -7 0 C. Sometimes sharp short-term decrease of temperature down to -40 0 C is observed. This is explained by the inflow of high-pressure air masses from the North or East.

Consistent snow cover lasts from the middle of December until the middle of March. In western parts it lasts 80 - 90 days on average, in eastern parts – up to 100 - 120 days. Due to frequent thaws, snow cover is not thick. It may reach 30 – 50 cm, on the coast 15 – 20 cm. In years of heavy precipitation and during cold winters it may reach 1 m, while during warm winters snow cover is inconsistent. The average number of days with thawing is < 60 days per year.

2.3. WINTER INDEXES

Winter severity indexes for broad socioeconomic needs are not calculated in Latvia. However, there is a possibility to do it, since Latvian Hydrometeorological Centre handles all necessary data and provides information about actual deviations from the average values: decade or monthly temperature, precipitation, as well as, thickness of snow cover.

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

Road routine maintenance standards, including requirements for winter works, are defined in the Road Traffic Law and State Regulation "Requirements for Routine Maintenance of State and Municipal Roads and Performance Supervision Procedure" (updated in 2010).

Roads are divided into 5 winter service classes according to road importance and traffic flow:

AADT (vehicle per day)	**Main roads**	**Regional roads**	**Local roads**
> 5,000	A	-	-
1,000 – 5,000	A1	A1	A1
500 – 1,000	A1	B	B
100 – 500	-	C	C
< 100	-	-	D

Each service class has definite requirements for the state of road during certain weather conditions:

Requirements	Maintenance class				
	A	A1	B	C	D
	Acceptable conditions				
Average snow depth					
No precipitation slush	snow free	snow free	4cm	10 cm	no limits
during snowfall fresh	6 cm 3 cm	6 cm 3 cm	8cm 5cm	10 cm 6 cm	no limits
Ruts	up to 10 mm	up to 20 mm	up to 40 mm	up to 50 mm	No limits
Time for cleaning	3 h	4 h	6 h	18 h	No limits
Time for skid prevention	3 h	4 h	6 h	no	No limits

In practice it means, that for A and A1 classes "bare pavement policy" will be provided with intensive use of snow melting agents, while B class allows anti-skid treatment mainly with abrasives. C and D classes provide only passability, without predefined anti-skid measures:

In the winter of 2015/2016 service level for state main and regional roads can be seen in the following map:

Requirements for equipment, materials, work performance and expected results are defined in the-

se specifications. Snow ploughing on state roads is mostly performed by trucks equipped with front and side ploughs. Wet salt is used for skid prevention on A and A1 class roads. Maximum dimension of a salt particle may not exceed 6.3 mm; various dashes may not exceed 2 %. Wet salt, salt & sand mix or pure sand is used, as well as, grooves are worked in the road surface for skid prevention on B class roads. 1 m3 of salt and sand mix has to contain at least 10 % of salt. Maximum dimension of a mix particle may not exceed 6.3 mm. On C class roads skid prevention activities are performed only in separate sections – in intersections, on steep elevations and sharp turns, by spreading sand or working in grooves in the road surface. Wet salt is used to melt ice on streets in bigger cities. In the case of heavy snowfall, streets are cleared by making snow banks along the side of the streets. Snow removals are organized later. Rural municipalities mainly clear their own roads and streets.

3.2. ORGANISATION AND OPERATION OF WINTER MAINTENANCE

The state-owned maintenance company (the contractor) is responsible for maintenance of state roads in winter, while respective municipalities are responsible for maintenance of municipal roads and streets. State road maintenance in winter is financed from the state budget, and maintenance of municipal roads and streets is financed from municipal budgets that receive earmarked subsidies from the state budget.

SJSC "Latvian State Roads" (LSR) prepares a programme of winter road maintenance, classifies road network and calculates the necessary funding. In the winter of 2015/2016 state roads were classified as follows:

Class	Total km	Including		
		Main roads	Regional roads	Local roads
A	689	599	90	-
A1	2,396	1,156	1,171	69
B	2,899	-	2,423	475
C	12,449	-	1,789	10,660
D	1,814	-	10	1,804
Total	20,247	1,755	5,483	13,008

The programme is approved by the Ministry of Transport. Basic data for the programme is prepared by the LSR local offices, while the central office summarizes and makes the necessary corrections to provide unified maintenance policy.

Contract for road routine maintenance (incl. winter works) was granted by law to a state owned contractor. The state road network is divided in 26 maintenance districts. Principle of "unit price" payment is used for performed works.

The contractor undertakes full responsibility for road conditions to comply with the defined maintenance class, performs regular supervision and decides on activities to be performed, based on visual inspections, weather forecast, RWIS data and experience. During winter, each district has a person on duty, who keeps in contact with the contractor and the road users, transport enterprises, emergency services, LSR TIC and local municipalities. There are 60 road weather stations (RWIS) along state main and regional roads. Future plans include the renewal of existing RWIS, as well as, installation of new, fully and partly equipped (IP camera and air temperature sensor) RWIS.

Information on temperature and moisture, precipitation and visibility, wind speed and direction, as well as, road temperature and condition is updated on a regular basis in a database. All RWIS are equipped with IP cameras. Some RWIS are equipped with soil temperature probes. All road maintenance units have access to data through the Internet. Persons on duty (contractor's staff) provide regular (every 2 hours) announcements about current road conditions based on the data from RWIS, as well as, periodic field observations. This information is accessible to everybody on LSR web page and is used to inform drivers through other media channels,

including Waze and Twitter.

3.3. ASSESSMENT OF SNOW AND ICE CONTROL MEASURES

The aim of winter road maintenance is to ensure traffic flow for functioning economy. So far the losses and benefits to the economy influenced by the winter road maintenance have not been precisely measured.

LSR keeps the register of all complaints and applications of road users; they are processed and replied to. For anti-icing and de-icing, mostly wet salt technology, as well as, salt and sand mix is used. Sand spreading and forming of grooves in compacted snow are used for skid prevention on low intensity roads.

Used technologies	Percentage
Wet salt	88 %
Salt and sand mixture	9 %
Sand	1 %
Grooves	2 %

At present, mostly heavy-duty trucks equipped with several ploughs are clearing roads of snow. Their efficiency is many times higher than that of slow equipment used in the past.

About 80 % of spreaders are included in a fleet management system (including technological sensors). This system provides the contractor and LSR with real-time and recorded information on performed activities through web interface. Another tool is data input in an electronic work log. Records of performed road routine maintenance measures and corresponding procedures of work approval lead to more productive communication between the contractor and the supervisor.

LSR local offices supervise the quality of performed works and approve the work. The final decision on payments is made by the Ministry of Transport. LSR personnel inspects the compliance of state roads to the maintenance classes and check the quality and quantity of performed works.

3.4. TRAFFIC SAFETY AND INFORMATION

LSR has founded a Traffic Information Centre. The person on duty at the Traffic Information Centre follows the situation on state roads, replies to road user inquiries and informs the contractor about road user claims. Road users can receive information about current driving conditions on state main roads and general information about driving conditions on roads in each district in the LSR webpage, mobile application Waze and social media.

LSR is working on schemes for effective and unified distribution of traffic information to the society with other authorities, which have or generate their own road data (emergency services, local and urban road departments, etc.). Data from LSR monitoring systems is also accessible to road users (RWS, traffic profiles, camera images) through convenient web interface (GIS). LSR webpage forms a national platform for all public traffic data. Another direction is providing traffic data for commercial services, which are dealing with on-route informative applications (interfaces: navigators, smartphones, etc.).

Before the start of winter season, LSR prepares information campaign on road maintenance policy in winter for drivers, as well as, distributes the information in the monthly newspaper "Road Newspaper", available free of charge in petrol stations and other public places.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

LSR is working on different ITS implementation and pilot projects that are closely related to road winter maintenance. One of the benefits of the SMART E67 project will be VMS (variable message signs) along the Via Baltica route that will complement the existing and new RWS with visual warning information about road

conditions. There are also some commercial R&D projects in this field that aim to support the process of decision making for anti-icing (preventive treatment) strategy. Another direction is the constant work on the improvement of overall methodology for road winter maintenance (level of service, evaluation criteria, payment system, etc.).

5. REFERENCES

www.lvceli.lv
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LITHUANIA Version 2014

1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

Lithuania is an Eastern European country on the Baltic Sea. From the regional point of view, Lithuania is often described as a Baltic state. It is situated in the geographical center of Europe. The area of the country is comparable to that of Ireland and Latvia. The coastal line of Lithuania is 99 km long.

Vilnius is the capital of the Republic of Lithuania. It is the largest city of the country with the population of 544,000. The historic center, or the old town of the city, is among the largest in Eastern Europe and occupies an area of 360 hectares. Its unique value was acknowledged by the UNESCO and in 1994 the old town of Vilnius was included into the UNESCO World Heritage List. Vilnius is situated in the south east of Lithuania (54°41″ Northern latitude and 25°17″ Eastern longitude) and is the administrative center of the country with the main political, economic, social and cultural centers.

1.2. ROAD NETWORK AND TRAFFIC

Area	65,302 km²	
Population	3.35 million	
Length of state roads	Main and national roads	6,700 km
	Incl. motorways	310 km
	Regional roads	14,600 km
Municipal and other roads	Local roads	59,400 km

The road network of national significance consists of main roads (1,750 km, including 310 km of motorways), national roads (4,950 km) and regional roads (14,600 km). 64 % of roads have asphalt or concrete

pavement. The total number of vehicles in the country amounts to 2.1 million.

Lithuania is situated at the crossroads and has international transport corridors extending from the north to the south and from the east to the west. Hence, the development of the road network and its maintenance is among the country's top priorities.

2. CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

Climatic conditions. Geographical position: Lithuania is located in middle latitudes, fairly close to the sea and the ocean. From the point of view of the country's climatic variety, it is described as being located in the northern part of the climatic zone of middle latitudes. The climatic region of the Baltic seashore is closer to the climate of Western Europe. For a longer period of a year the weather in Lithuania is determined by atmospheric fronts, the number of which reaches 160-170 per year.

Forests. Forests cover 31.7% of the country's area.

Waters. The country has approximately 748 mm of rainfall, whereas only 512 mm volatilize away. The remaining part, 236 mm (or 32% of rainfall) flow down to the sea by the surface of by underground flushes directly or through neighboring countries.

Internal water bodies of Lithuania (rivers, lakes, ponds and the Curonian Lagoon) cover 1903 km2, which is 2.9% of the country's area.

Rivers. Lithuania is crossed by 17 rivers longer than 100 km. The longest river is the Neman's, starting in Belarus, southwest of Minsk. It is the 14th longest river in Europe and the 4th in the watershed of the Baltic Sea. The total length of beds of rivers and canals in Lithuania amounts to 76.8 thousand km.

Curonian Lagoon. The largest internal water body in Lithuania is the Curonian Lagoon. It is a large lagoon of the Baltic Sea, separated from the sea by a narrow and long spit of sand. The total area of the Curonian Lagoon is 1584 km2, of which 413 km2 in the northern part of the lagoon belong to Lithuania.

2.2 STATISTICS ON TEMPERATURE

The average winter temperature fluctuates from -3 °C at the seaside to -6.5 °C in the Eastern part of Lithuania. In summer the average temperature is rather stable and its fluctuation is less varied (from +17 °C to +18.5 °C).

The length of the factual solar radiation in Lithuania comprises 50-55% from the maximum. The average length of the solar radiation per month ranges from 30 to 290 hours. In summer the average length of the solar radiation is 9.3-8.6 hours per day. In December the sun shines approximately for 1 hour per day.

Air humidity. The highest relative humidity (more than 90%) is usually at the beginning of winter, while the lowest (around 70%) can be expected in May. It becomes lower from the sea front towards southeast.

Fogs are frequent in Lithuania, especially in western regions (90-105 days per year; general duration of fog amounts to 600-650 hours).

Cloud cover. The cloud cover in Lithuania is 7 points on a 10-point scale (i.e., cloudy with bright intervals). In a year, fine days are 6-10 times fewer than cloudy ones.

Snow cover. Approximately on November 15, at the earliest, the snow cover is formed in northern and eastern regions of Lithuania, while about 10 days later, at the latest, it is formed on the sea front. In snowy winters the thickest snow cover reaches even 90 cm. The thickest average snow cover (around 30 cm) is usually on the eastern edge of Lithuania. In snowy winters the snow cover remains the longest (around 105 days) in North East Lithuania. Usually the snow cover disappears by March 25.

Blizzards are rather frequent in Lithuania. Days with blizzards in Samogitia and East Lithuania average more than 20. There have been winters, when blizzard storms lasted for 55 days. The average duration of one blizzard is 6-7 hours.

In Lithuania precipitation is mainly liquid (around 75%), mixed (17%), and hard (snow, ice; 8%). The rainfall in Lithuania averages 1,000-1,300 hours per year (in some years up to 2,000 hours; there are around 190 days with fall here).

3. WINTER ROAD MANAGEMENT

3.1 STANDARDS & RULES

The Lithuanian Road Administration (LRA) is a public institution established by the Government of the Republic of Lithuania and is in charge of organizing and coordinating the rehabilitation, maintenance and development of roads.

Roads of national significance are divided into main, national and regional roads. Each road category is maintained following one of three maintenance levels: high (level 1), medium (level 2) and low (level 3). The level of maintenance applicable for a particular category of roads is selected by the LRA considering the level of financing. The level of maintenance is approved by the LRA when concluding road maintenance contracts with state maintenance companies. Before each winter season, they identify routes of road cleaning and spreading and make schedules, which are approved by the LRA.

Since the year 2002 Lithuania has had the Road Maintenance Management System. The system is described in the Road Maintenance Manual. It consists of 6 units and includes standards of road maintenance, economic standards of road maintenance, technology of work execution on roads, preparation of road maintenance program, road technical control, acceptance of works and payment, accounting of road maintenance works and standards of works, equipment and material consumption for road works. Anyone interested in the standards can refer to tkti@tkti.lt.

For main and national road spreading the 'pre-wetted salt' method is used, which helps decrease the amount of salt. As a rule, when spreading NaCl, from 5 to 30% of CaCl2 solution is inserted. Under extreme weather conditions (strong freezing rain, low weather temperature) roads can be spread with sand and salt. It improves the skid resistance. Regional roads are spread with a mixture of sand and salt or just sand. When the temperature falls lower than -8°C, roads are spread with a mixture of sodium chloride and calcium chloride (NaCl and CaCl2) at the proportion of 88:12. Proportions might vary. The capacity of salt spreaders is from 5 to 7 m3. Depending on the quantity of salt and the width of the spread, one salt spreader can cover from 15 to 50 km, 30 km in average. In Lithuania, there are about 120 days when spreading is required. The anti-icing strategy allows reducing the amount of chemicals spread on the roads by 20-40%. NaCl, when pre-wetted by CaCl2 solution, is less likely to cause corrosion, particularly if a small amount of inhibitors is added (e.g., some phosphate).

There are no marked differences between the climatic zones in Lithuania. Therefore, they hardly influence the length of spreading.

In accordance with the standards enclosed in contracts signed with contractors, the maintenance operations should start not later than 1 (one) hour from the beginning of rain, snow or freezing rain. Level 1 (approximately 200 km) maintenance operations (24 hours a day) of main roads are applicable on road A1 Vilnius -Kaunas-Klaipėda the road section from 10 to 115 km, i.e., from Vilnius to Sitkūnai, and road A5 Kaunas–Marijampolė–Suvalkai.

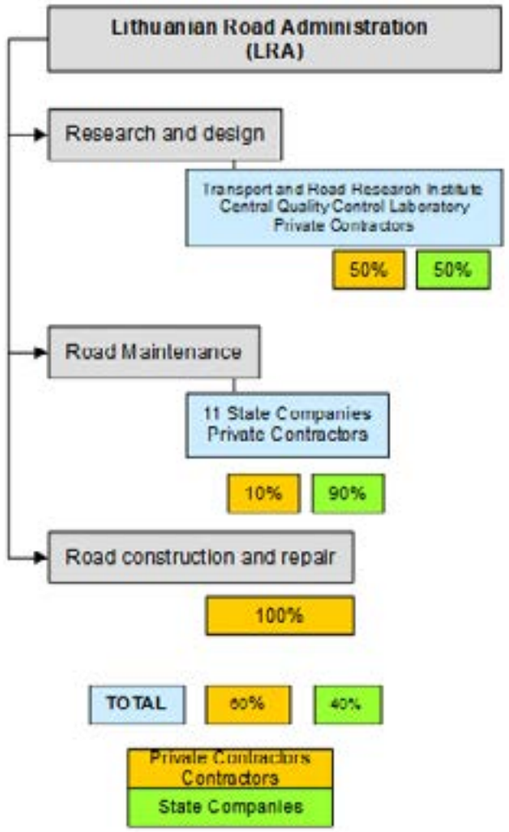
The maintenance service is on duty on other main roads from 4 to 22 hours, on national roads—from 6 to 19 hours, on regional roads—from 9 to 18 hours. From 10 November to 1 April vehicles with the total permitted weight exceeding 3.5 tonnes are not allowed to drive with summer tires in Lithuania. From 10 April to 1 November vehicles with studded tires are not allowed.

In Lithuania the relief is very flat, therefore, winter chains are hardly ever used and their use has not been defined.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Transport and Road Research Institute and the Quality Control Laboratory are state enterprises. Road reconstruction projects in Lithuania are prepared by private design companies. Projects of a smaller scope can be prepared by the Institute and the Laboratory themselves. The majority of maintenance operations are performed by the road state maintenance companies. However, for some works private contractors are invited. Some equipment can be rented. Roads are constructed and reconstructed exclusively by private companies, on a contractual basis. The Lithuanian Road Administration (LRA) invites tenders for the works performed by private companies. The road maintenance is financed from the national budget (Road Maintenance and Development Program). 40% of the total amount for maintenance is allocated for winter maintenance. In the winter season of 2008-2009 the total sum of winter maintenance funds amounted to EUR 38 million.

Road maintenance in Lithuania is performed exclusively by state maintenance companies, which is why there are no tenders for road maintenance works. State maintenance companies, in charge of road maintenance operations, may hire contractors for some operations or rent some equipment.



OPERATING MANAGEMENT OF ROADS

Local roads and streets in cities and towns are within the responsibility of municipalities. They are in charge of road and street maintenance. Companies subordinate to the LRA are in charge of maintaining state roads. The funding for that category of roads shall not be used for local roads.

In Lithuania, even when winter is very harsh, there are no restrictions imposed on using roads. They are never closed. Main roads shall be accessible round the clock.

The traffic may only be interrupted under extreme weather conditions for no longer than 2 hours on motorways, no longer than 3 hours on other main roads, no longer than 8 hours on national roads, no longer than 48 hours on regional roads. The traffic is interrupted at the seaside area, which is flooded with melt-water from rivers in spring. Each year approximately 100 km of roads are flooded. Due to the same reason there might be weight restrictions imposed (up to 8 tons) on gravel roads in regions. There are no standards providing for the closure of roads or restriction of traffic. The issue is dealt with from the practical point of view, whether you can drive on the road and if the heavy vehicle does not damage it. The main parameter for the total weight of the vehicle is the depth of ground freeze.

The measurements of snow and ice are performed by the road maintenance companies. The quality of their work is under control of inspectors of the central Quality Control Laboratory.

The meteorological service of Lithuania broadcasts short-term (3-6 hours) weather forecasts for road specialists 5 times a day; a long-term (for the whole week) weather forecast is given once a day.

In the year 1998 on the basis of the Swedish company AerotechTelub the LRA set up the Road Weather Information System and started accumulating data on the road weather conditions. The data from field stations are transferred to the central computer located at the LRA. The data are accumulated, stored and processed in the server. The data users are of two categories: all road users and road maintenance specialists. The latter have their own special webpage which provides data from all field stations. In 2009, there have been 48 field stations installed and 27 video cameras. Road maintenance offices receive information on the road condition to their office working stations, whereas information is also provided to the public in the mass media and the LRA webpage (www.lra.lt).

The development of the traffic information system of the roads of national significance has commenced. At the present time activities of intelligent transport systems that are in line with the capabilities of the Lithuanian Road Administration and possible links with other intelligent transport systems in Lithuania are established, further possibilities and directions in the development of the traffic information system of roads of national significance and joining the single network of intelligent transport systems of Europe are provided for. The European Union is going to finance the project in part; the funds will be allocated from the European Regional Development Fund.

It is planned to implement the project within two years, the new system should start to operate in Lithuania at the end of 2010. These will be technologies,

providing information about traffic conditions, traffic disruptions and traffic control measures used on the roads. When installing a modern traffic information system on Lithuanian roads of national significance, the following new electronic services will be started to be provided to the users:

information about road works, their duration, detours, possible delays due to road works;

real time information about traffic intensity and the average speed on separate sections of the road, warnings about traffic disruptions. Short-term forecasts of traffic intensity (on the roads where sensors of traffic intensity are installed). Information about possible delays due to traffic disruptions;

information about restrictions on the roads due to climate conditions, traffic accidents or any other reasons. Information about duration of restrictions, detours, possible delays;

information about the weather conditions on the roads, information about the condition of the road pavement (slippery ground), warnings about phenomena that are dangerous to traffic;

planning of routes taking into consideration traffic restrictions and traffic conditions (a search for the shortest way, a search for the fastest route, a search for a rational way).

The traffic information system will be developed by installing sensors on the roads, which are necessary to collect information about traffic conditions and setting up the Traffic Information Center.

The technical servicing and maintenance of the field stations, variable message signs and video cameras are within the responsibility of a division of the central Quality Control Laboratory.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

Each year the LRA considers traffic volumes on the roads and the budget allocations, then with the help of RIS identifies road maintenance levels. The last estimations testify to the fact that optimum road maintenance, including winter road maintenance, requires the funding that is two times higher than the present allocations from the Road Maintenance and Development Program. Therefore, the efficiency of the road maintenance service conforms to the level of funding.

The central Quality Control Laboratory is in charge of road maintenance control, which is performed on a contractual basis. Regional inspectors at clearly defined intervals or after changes in the weather conditions inspect roads. The function is solely within the responsibility of regional road administrations. They identify if the quality of road works conforms to the requirements of the Road Maintenance Manual. Winter road maintenance works are attributed to routine maintenance. They are paid considering the resultant quality.

3.4 Traffic safety and information

The LRA collects information about the weather on roads and road condition in several ways. One of them is concerned with transferring information from regional administrations by telephone—twice a day. Another pertains to electronic transfer using the LRA information system—twice a day.

The third way is concerned with collecting information from the RWI system (in winter time every 15 minutes). The LRA processes the information and sends it to the mass media and the webpage of the LRA (www.lra.lt) four times a day. Also information on traffic restrictions is provided. The information is also radio broadcast. Other mass media receive it via news agencies. The information is transferred in electronic form. The LRA webpage provides information from all field stations.

On the Vilnius–Kaunas–Klaipėda road there are four variable message signs (VMS) installed. They provide data on weather conditions from the nearest field stations or any other information. The VMS are managed from the road maintenance company or the LRA.

Road users receive the following information on traffic accidents, their causes, traffic conditions etc.:

1. The following information on traffic accidents and their causes is given to news agencies, radio stations and television, the press, electronic mass media: on the situation during the day, week, month/s, year;
2. Publications (brochures, leaflets, calendars etc.) are prepared, printed and distributed;
3. Measures of safe traffic for children in winter time are taken: education on traffic peculiarities, skiing and other winter sports and their location etc.).

A system of improving traffic safety

In 2008, 4,897 fatal and injury accidents (with 498 people killed and 5,940 people injured) occurred. If compared to 2007, the number of accidents in 2008 redu-

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ced by 24.1%; the number of killed by 32.7% and the number of injured by 26.1%.

To improve the traffic safety situation, the following measures have been taken:

Education (information in mass media, publications on traffic safety, instructing pedestrians, cyclists and horse drivers how to use reflectors);

Engineering measures (lighting road sections, fencing, reconstruction of intersections and some road sections, constructing cycle tracks and pedestrian walkways, new roundabouts, speed humps, reflectors in road pavement, guardrails, etc.);

Control of road users (administrative measures); more attention is given to the control of tires and lights;

Special campaigns of traffic safety when education and control is coordinated.

From 1 November to 1 April the speed of transport on motorways is reduced. One of the most effective speed reduction measures was the installation of the network of speed enforcement cameras on the state roads. In 2007, there were 2 units, in 2008 – 12 units, in 2009 – 139 units installed.

The estimate of one killed person in Lithuania is approximately 2 million Litas (about EUR 0.58 million). One of our top priorities in the near future is the improvement of road traffic safety. The focus would be on road maintenance, including winter maintenance, by increasing financial allocations so that the accident rate drops to that of the other EU member states.

4. On-going Research and Studies to Improve Winter Management

Vilnius Gediminas Technical University from the very beginning of the RWIS has been involved in the data processing (1998) received from the field stations. Specialists of the University also analyze the data and provide forecast, identify the levels of road maintenance.

Road Maintenance Group at the Baltic Road Association is in charge of coordinating the work of all maintenance services of the three Baltic States. Members of the group exchange information on the development of road maintenance structures, introduce new national standards and other documents on road maintenance. They also submit proposals which serve as the basis for the countries when organizing the work of road winter maintenance services on the Via Baltica road and other international roads.

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MOROCCO Version 2014

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

The Kingdom of Morocco has a surface area of 710,850 square km. It is located in northwest Africa, merely 15 km south of Spain across the Strait of Gibraltar. Morocco is bordered by Mauritania to the south and Algeria to the east. It has a population of 30 million inhabitants, half of which live in urban areas. It has a Mediterranean climate in the north, an Atlantic climate in the west and a desert climate in the south. The climate is also generally temperate due to its proximity to the sea (approximately 3,000 km of coastline). The capital of Morocco is Rabat. Morocco's major cities include: Casablanca, Rabat, Tangier, Agadir, Tetouan, Fez, Marrakech, Meknes and Safi.

1.2 ROAD NETWORK AND TRAFFIC

The Moroccan road network, which is managed by the Direction des Routes (Road Administration), consists of a total of 57,347 km of roads, of which 38,545 km are paved and 18,802 km are tracks.

The paved road network is classed according to three categories:

national roads totaling 9,994 km;

regional roads totaling 9,324 km;

provincial roads totaling 19,227 km.

This network undergoes standard maintenance throughout the year provided by the Administration and periodic maintenance (strengthening, surfacing, widening, road marking, etc.) carried out by private companies.

The highway network comprises approximately 920 km and 555 km of highway is under construction. This network is managed by the Société nationale des autoroutes du Maroc (National Highway Department of Morocco).

In 2008, road traffic reached 66.01 million vehicle-kilometers/day, against 60.41 million vehicle-kilometers/day in 2007, which is equivalent to a 9.27 rate of increase. The total number of vehicles on the road is approximately 2.2 million.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS AND MAIN WINTER OCCURRENCES TO DEAL WITH

The climate in Morocco is very different in each region. Coastal areas enjoy a temperate climate which contrasts with the desert climate in the southern and eastern areas of the country. Although, considered a

hot country, nevertheless, Morocco's climate is varied. With a Mediterranean climate in the north, an oceanic climate in the west, a continental climate inland and a desert climate in the south, the country's climate clearly varies according to the seasons.

The summer is generally hot and pleasant on the coast and in mountainous areas, but is stifling in the south and in major cities. In winter, coastal areas experience relatively mild temperatures. In contrast, the winter in the elevated areas, which constitute a large part of Morocco, is cold and very humid.

On the western coast, average temperatures for the coldest and hottest day range between 8 °C and 21 °C in winter. In summer, temperatures range between 17 °C and 27 °C. Average winter temperatures inland range between 4 °C and 20 °C. Winters are cold and rainy with frequent frost and snowfall in the Middle and High Atlas. In these regions, snowfall is abundant during winter and can extend until May, and on the rare occasion, temperatures can drop to -18 °C, whereas during summer, temperatures are quite pleasant, averaging 20°C.

The rainy seasons are generally between October and November and between April and May. It should be noted that the Rif region, in north west Morocco is the wettest area in Morocco.

The Moroccan Sahara and pre-Sahara have a dry desert climate. Even in winter, the climate of the desert is hot and dry during the day, but becomes very cold at night.

2.2 WEATHER STATISTICS

In Morocco, services relating to weather and climate information and forecasts are provided by the Direction de la Météorologie Nationale (DMN) (National Meteorological Services Department). This data concerns a range of requested climate products relating to temperature, precipitation, wind, humidity, snow, fog, hail, etc.

General weather forecasts may have a range:

- of or less than 48 hours:
- weather forecast bulletin for 1 to 4 parameters;
- weather forecast bulletin for more than 4 parameters;
- of 72 hours:
- weather forecast bulletin for 1 to 4 parameters;
- weather forecast bulletin for more than 4 parameters;
- of five days (medium range):
- medium-range weather forecast bulletin.

The DMN currently has 44 weather stations. Its strategic program provides for the modernization and expansion of its network.

In Morocco, annual rainfall is approximately 810 mm in Tangier, 550 mm in Rabat, 400 mm in Casablanca, 250 mm in Marrakech and Agadir, 350 mm in Oujda, 1200 mm in Ifrane and 30 mm in Dakhla.

2.3 WINTER INDEXES USED IN THE COUNTRY

Generally, in Morocco, winter season is characterized by the number of days of snowfall, the snow depth recorded on the road network, and the number of hours that road access is blocked because of poor winter conditions. Therefore, the past three years have been marked by the following conditions:

De-scription:	2005/2006	2006/2007	2007/2008	2008/2009
Number of hours of road blockage	5223	1027	700	9660
Number of days of snowfall on roads	17	15	12	74
Kilome-ters of snowy roads	4251	3714	2486	4900

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Road traffic is governed by the Code de la route (Highway Code) of 1953 whose amendments have recently been passed by the Chamber of Representatives.

In terms of winter services, there are no established standards regarding snow removal. Winter preparation is carried out by means of a circular published by the Direction des routes which outlines the strategy to adopt as regards preparation and intervention.

The signage for snow-covered sections complies with Moroccan directives regarding road signs. Prescriptive signs are installed along the road network in accordance with a by-law approved by the ministre de l'Équipement et des Transports (Minister of Public Works and Transportation).

Road blockages and closures due to snow are announced through press releases issued by the Direction des Routes and are broadcast on the radio and television in Morocco, so that the general public remains informed.

Snow removal is generally carried out by means of snowplows (trucks or graders) except when snow depth exceeds 50 cm. In this case, it is necessary to use snowblowers.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Direction des Routes (DR) is an operational department of the ministère de l'Équipement et des Transports (MET) (Ministry of Public Works and Transportation). Within the territory, it is represented by 16 regional public works and transportation divisions (DRETs), 36 provincial public works and transportation divisions (DPETs) and 7 logistics and equipment departments (SLMs). The latter are independent entities. They provide all DRETs and DPETs with the necessary equipment (heavy equipment and trucks) to ensure routine road maintenance as well as snow and sand removal.

One fundamental task of the Direction des Routes (DR) is to consistently and safely provide road users with a sustainable traffic flow on the road network. However, the road network is subject to natural phenomena which hinder traffic flow at different times during the year. Snow cover, sand cover and landslides are among the most common phenomena in Morocco. Snow cover is frequent in the Rif region, from the Middle to High Atlas which spans approximately 5,000 km. Sand cover occurs in the desert areas, south of the Kingdom. Dealing with these phenomena constitutes a major concern of the DR.

In terms of winter service, the strategy of the ministère de l'Équipement et des Transports is based on:

- maintaining the safety of road users at all times;
- re-establishing winter service as expeditiously as possible to ensure traffic flow.

In terms of re-establishing road service (regarding snow removal, flood, rockfall, etc.) in general, all operations are prioritized as follows:

- First, there is intervention on the structured and strategic network to enable inter-city travel as well as the delivery of consumer products from economic hubs.
- Second, there is intervention on the network with medium-level traffic to access administrative centers of rural towns, then intervention on the local network.
- Following the intervention on the main network, teams in the territory of the MET assist in relieving the isolation of the most remote rural population.

In terms of snow removal, the Direction des Routes acts according to the order of precedence of interventions, based on each type of network. The aim is to re-establish general service on the road network as quickly as possible for any given province and, therefore, first of all, access to goods and services, followed by easy travel for the local population.

The ministère de l'Équipement et des Transports has 800 heavy equipment machines and trucks, including 105 specific snow-removal machines (snowblowers, snowplow trucks and graders) and 15 trailers for transporting equipment nationally and regionally.

Since snow-removal operations cannot be carried out simultaneously throughout the snow-covered road network, it is necessary to prioritize roads based on their economic and strategic importance. As a result, three levels of service have been specified:

Service level S1 (1,850 km)

Roads classified in this level of service receive continuous service (except during snow storms) both day and night, in order to consistently and adequately ma-

intain traffic flow or, if necessary, within a short period of time, not more than 4 hours following a snow storm. In general, national and major regional roads are classed in this level.

Service level S2 (1,700 km)

Service on the roads classed in this level of service is not continuous. However, it is requested that acceptable traffic conditions are maintained during the day by organizing, if necessary, convoys when there is persistent snowfall.

Service level S3 (1,360 km)

No time limit has been established for roads classed in this category. Acceptable traffic conditions are established as soon as possible.

The road network experiences relatively significant snowfall according to the region and the time of year. The period of highest snowfall lasts from November to March. Within the region, the following measures are undertaken when there is snowfall:

- snow barriers are closed in case of storms;
- all snow-covered sections are monitored;
- traffic is redirected to alternative routes, if possible;
- interruptions in service are announced;
- the intervention plan is implemented to remove snow from sections where road service is interrupted;
- blocked sections are reopened;
- information is disseminated.

Every year, winter preparations begin during the month of September. These are done at two levels:

- Central level by the Direction des Routes ; and
- territorial level (by DRETs and DPETs).

At the central level, winter service authorities:

prepare a circular addressed to all DRETs and DPETs affected by the snow to mobilize human resources and equipment and carry out preventive maintenance operations at critical points of the road network;

- visit certain DRETs and DPETs to assist them and to acknowledge the measures taken regarding territorial winter preparations;
- hold a meeting with authorities at the office of the Direction des Routes to raise awareness and to verify that all office equipment (telephones, fax machines, photocopiers, etc.) is working well;
- visit all emergency bridges at Oued Zem (DPET at Khouribga) to find out about the preparations carried out.

At the territorial level, the DRETs and DPETs:

- prepare the office which must be equipped with, among other things, a fax machine, a telephone, radio communication equipment, a large map of the road network indicating all critical points and alternative routes (itinéraires bis) and the on-call program, etc.;
- verify and prepare snow-removal equipment and the radio communication system;
- carry out cleaning operations of sanitation works and ditches, maintain structures, maintain and/or replace vertical signage, put up markers (on the network covered by snow);
- visit critical points of the road network;
- maintain snow barriers and shelters;
- hold a meeting with adjoining DRETs and DPETs and winter service authorities of the DRETs and DPETs;
- provide de-icing materials (salt, grains of rice, pozzolana, etc.) to eliminate ice.

It is interesting to note that employees who work to maintain winter services are provided with basic services: accommodation, supplies, clothing, heating, bonuses for hard work, etc.

An external analysis identifies the opportunities and threats presented in the environment. These will be evaluated according to the PESTEL (political, economic social, technological, environmental, legislative) strategic analysis model.

Winter road service constitutes a serious issue in terms of its impact on these different factors.

Political factor

Increasingly, winter service is attracting the attention of officials and local authorities. In fact, they are becoming aware of the interruptions in road service caused by snow. Their concerns are echoed in press releases, questions posed in Parliament, letters addressed to the Ministre de l'Équipement et des Transports, etc.

Local and national officials are concerned about winter service, either because this action seems profitable and beneficial to their electoral efforts, or because they in turn, face pressure from road users, merchants, their associations and from the general public.

As decentralization takes place, winter service management in urban areas falls under the authority of local officials. Regarding local authorities and decentralized services, particularly external services of the Ministère de l'Équipement et des Transports, these are responsible for public safety, traffic flow, the continuity of public services, the sustainability of economic activity, etc., within their area of expertise, under the supervision of their ministry. In principle, territorial communities (local authorities, municipal councils, regional councils) work jointly.

Economic factor

To state the obvious, the road is a key element in modern economic activity and the population's mobility. As such, in Morocco, 90% of the population use the road network and 75% of goods are transported via the road network. As a result, any interruption in road service is detrimental to the population and to economic and commercial activity.

Although snow has already become an economic asset (ski resorts, etc.) in the 20th century, it continues to pose many problems for those who, over time, have attempted to reduce its influence and negative effects.

Road network interruptions due to snow are expensive and very costly to the community.

They:

- affect economic and commercial activity;
- reduce personal travel to tourist destinations;
- cause a shortage of food and disruptions in pharmaceutical supplies.

Consequently, the prices of essential products increase and affect the purchasing power of the population. This is already low since the areas concerned are all under developed.

Social factor

Road service interruptions due to snow on the network exacerbate the isolation and remoteness of many communities and hinder the transport of people and goods. They prevent access to health care and to educational and socio-administrative centers. These interruptions disrupt children's schooling. As a result, they cause dissatisfaction and discontent among the population and sometimes create a feeling of marginalization and exclusion. In fact, since road users are increasingly aware of the importance of quality and continuous service, they resort to complaining and protesting.

While infrastructures undeniably serve as a means of anchoring the population in certain disadvantaged geographic areas (mountains, areas that are far from urban centers, etc.), on the contrary, service interruptions encourage rural migration and cause rural communities to become deserted.

Technological factor

Increasingly, winter service incorporates technology:

- Road users can contact the Minister or send him messages to express their satisfaction or dissatisfaction via NICT (the Internet, GSM, etc.).
- Road users can express their opinion via the press, radio or television.
- Thanks to weather reports: weather forecasts can be used to better prepare for winter (planning head, prevention, positioning equipment at hot spots, etc.).
- Effective snow-removal equipment has a GPS and radio communication system and air conditioned cabins.
- Automatic salting spreaders to de-ice roads.

Ecological and environmental factor

Winter service has a significant impact on the environment due to:

- the over consumption of fuel and of lubricants;
- road de-icing chemicals (salt) that pollute the water table and decrease flora.

Road maintenance activities and operations are likely to affect the quality of native environment located near to roadways. In Morocco, ecological and environmental concerns are considered when developing and implementing winter service projects. Therefore, as regards road de-icing chemicals, we use pozzolana, a natural material that is found in abundance in Ifrane and

Khenifra regions, and which makes it possible to reduce the impact on flora and fauna and on the water table.

Legislative, legal factor and safety instructions

Winter service requires strict compliance with legal and statutory provisions which govern management and organization. It is particularly important to act in strict accordance with the provisions of the Highway Code. When there is snow, safety standards especially include complying with signage, driving in convoys, obeying speed limits, maintaining safe distances between vehicles and snow barriers, etc.

Besides weather reports, television networks and radio stations regularly broadcast reports regarding road service interruptions due to snow and the closing and reopening of roads.

Road users have access to a telephone number for the DR (05 37 71 17 17) 24 hours a day, 7 days a week, so that they can learn about the present and progressive state of the road network.

Moreover, just as road users, snow removal officials must face the same traffic during their different operations and, as a result; they are exposed to potential hazards. Their safety must be particularly and constantly ensured, specifically through sufficient signage.

3.3 ROAD SAFETY AND ROAD INFORMATION

The first priority of Direction des Routes officials is the safety of road users. Provisions have been implemented to ensure the safety of road users and to avoid incidents on snow-covered roads.

Thanks to the vigilance of the winter service teams, we recorded no loss of human life on the snow-covered road network due to road service interruptions caused by snow. Before snow barriers are closed, teams always search snow-covered sections to ensure that there is no road user in these sections. These fences are only opened after snow-removal operations are completed and roads are treated with road de-icing chemicals. Travel in convoys, which often takes place on the snow-covered network, is always escorted by snow-removal equipment.

Internal communication

When there is road service interruption due to snow, the DRETs and DPETs concerned immediately communicate information to the DR and to the neighboring DRET and DPET by telephone at 05 37 71 17 17, by fax at 05 37 71 32 54 and by the information highway (SMS and the Internet).

*** Radio communication**

Since 1993, the DR has implemented a radio communication system based on VHF/UHF bands. This system, which is generally used in the 51 DRETs and DPETs, makes it possible to:

- control information;
- closely monitor intervention teams operating on the ground during snow removal operations, salting, sand removal and routine road maintenance, etc.;
- have a distinct communication network outside the congestion of existing networks;
- reduce decision-making time and prevent hasty actions and delays in the event of natural phenomena and as a result, improve the public utilities provided to road users;
- improve coordination between neighboring DPETs.

All maintenance and snow-removal equipment have a radio communication system.

*** Information highway**

In effort to modernize its management tools, in 2005, the DR developed a computerized system for managing information regarding road incidents of which there are five, involving snowfall, sand cover, traffic accidents, flood damage, problems with structures and road works.

This system, which is based on the Internet and on SMS messaging through GSM telephones, makes it possible to:

- improve the time taken to gather information;
- share information, in real time, with different officials at the Ministère de l'Équipement et des Transports to assist decision-making;
- improve the storage of information for the general public;
- create a database of road incidents.

Therefore, information on road incidents is sent either by SMS from the incident site in the form of summarized information or through the Internet. In this case, the authorized system user adds information on road incidents. The information communicated includes the number of the road, the kilometer marker, the type of incident, the death toll and possibly, an incident report.

The system also enables the administrator to semi-automatically prepare press releases regarding traffic conditions (in French and Arabic) and send these to recipients attached with maps indicating the location of the incident.

External communication

*** Telephone number: 05 37 71 17 17**

As regards information for the general public, the DR allows access to a telephone number (05 37 71 17 17) that can be used 24 hours a day, 7 days a week and which informs the public about the state of the road network, particularly concerning traffic conditions during snowfall.

*** Media**

Information is also broadcast to the general public through press releases on the radio, television and in the press. These press releases (regarding road service interruptions or the reopening of roads) are prepared by the service exploitation et viabilité (Operations and Winter Service Department) of the DR.

*** Signage with varied messages**

In terms of improving traffic conditions and the level of service on main roads, the DR has installed signage with varied messages to inform road users, in real time, about the state of the network, especially during snow removal when there are possible detours. Signs are installed on the following roads:

- at Meknes, on the RN8 at the Meknes exit towards El hajeb;
- at Fez, on the RN8 at the Fez exit towards Ifrane;
- at Ifrane, on the RN8 at the exit towards Azrou;
- at Azrou on the RN13 at the exit towards Midelt, in the middle of Ifrane.

These signs are managed by system control centers linked by a modem via the switched telephone network. The main control centre is located at the DPET in Ifrane.

*** Fax and telephone**

Information regarding road service interruptions and the reopening of roads is also communicated by telephone and fax to the local authority and the Royal Gendarmerie.

In order to follow weather changes and as a result of an agreement with the Direction de la Météorologie Nationale (National Department of Meteorology), the departments of the DR daily receive medium range (4 days) weather reports which include information on the weather observed and forecasted and, if necessary, weather reports with warnings concerning inclement weather and announcing snowfall.

In the case of alert bulletins, the central departments of the DR warn the external services concerned in due time, and very closely monitor the different operations carried out on the ground to mitigate the risks caused by inclement weather.

The territorial departments affected by these warnings launch reconnaissance operations to establish the status of critical points and monitor and verify the state of interruptions.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGIES

In terms of snow-removal equipment, since 2005, the Direction des Routes has acquired 31 snow-removal units and 3 additional snowblowers are currently waiting to be delivered. Each of these machines is equipped with a radio communication system.

Variable message signs (VMS) have been installed in Ifrane to inform users about road conditions.

4.2 NEW MANAGEMENT AND ORGANIZATION APPROACHES

The Direction des Routes is giving a valuable, strategic and creative dimension to its human resources. The

employees who work in the winter service sector are experienced and devoted and demonstrate a sense of membership similar to that of an elite group. These employees do not count their work hours and do their best to satisfy road users. New management approaches are based on the logic of intervention via the road. Limitations between provinces do not exist when it comes to snow removal operations. In fact, snow-removal teams in any given province continue to clear snow on the same road until they meet teams from other provinces.

Efforts have intensified for the development of forecasting and road monitoring (patrolling) in order to improve the reaction and response speed to weather conditions and environmental forces.

4.3 TRANSNATIONAL COOPERATION TO IMPROVE LEVELS OF SERVICE BETWEEN BORDERING COUNTRIES

The need to better manage winter service constitutes a major concern of the Direction des Routes. Since it was established, it has chosen to develop technical cooperation with its counterparts which include industrialized nations as well as developing countries.

This cooperation is aimed at improving management and procedures to respond to current and future issues encountered in the field of winter service.

Therefore, bilateral cooperation has been implemented between Morocco and other contributing countries in fields relating to winter service, such as:

- Cooperation between Morocco and Sweden in the field of road safety has provided the departments of the DR with technological tools for management, operations and road safety, with special emphasis on the information and operating system for snow-covered roads or roads subject to inclement weather. Significant recommendations have been presented that focus on the following aspects: snow removal equipment, road equipment, techniques for snow removal and ice elimination, information systems, and road infrastructure.
- Cooperation with Japan, which has resulted in the construction of an institute for equipment training and road maintenance. Since 1993, over 5,000 Moroccan technicians and 200 executives from African countries have benefited from training at the institute;
- Cooperation with France in the field of road signs has made it possible to develop a guide to road signage in urban areas and to introduce new road signs.

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NETHERLANDS Version 2014

1 DEMOGRAPHICS & ROADS

1.1 INFORMATION ABOUT THE COUNTRY

The Netherlands is a country small in size (41,528 km^2) with a population of 16.5 million inhabitants. That is an average of almost 400 inhabitants per 1 km^2.

The Netherlands is located in Northwestern Europe, and bordered by the North Sea to the north and west, Belgium to the south, and Germany to the east.

The capital is Amsterdam and the seat of government is The Hague. It also has one of the most free market capitalist economies in the world.

The Netherlands is a geographically low-lying country, with about 27% of its area and 60% of its population located below sea level. Significant areas have been gained through land reclamation and preserved through an elaborate system of polders and dikes.

The estuary of three important European rivers, which together with their distributaries form the Rhine-Meuse-Scheldt delta, forms a great part of the Netherlands. Most of the country is very flat, with the exception of foothills of the Ardennes in the far southeast and several low-hill ranges in the central parts created by ice-age glaciers.

1.2 ROAD NETWORK AND TRAFFIC

Area	41,528 km^2	
Population	16.5 million	
Length of road	Motorway	5,050 km[1]
	Regional main roads	7,848 km[1]
	Local Roads	123,237 km[1]
Latitude	51°53' N	

The road network comprises 5,050 km of motorways, 7,848 km of regional roads and 123,237 km of local roads, amounting to a total of 136,135 km of paved roads. The national fleet of 10.1 million vehicles includes 7.4 million passenger cars. Transport of freight is of great importance to the Dutch economy. A great deal of this transport takes place at night and in the early morning, particularly commercial traffic.

The economic importance of roads cannot denied, even in winter. As a result, one of the tasks of the road authorities is to keep the road network serviceable at all times, among other things by setting up a full organization for winter maintenance. The winter extends from October to May. The most severe winter conditions take place from the end of December until the beginning of March.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The Netherlands has a temperate maritime climate influenced by the North Sea and Atlantic Ocean, with cool summers and moderate winters. Daytime temperatures vary from 2 °C – 6 °C in winter and 17 °C – 20 °C in summer. Because the country is small there is little variation in climate from region to region, although the marine influences are less inland. Rainfall is distributed throughout the year with a dryer period from April to September. Especially in fall and winter strong Atlantic low-pressure systems can bring gales and uncomfortable weather. Sometimes easterly winds can cause a more continental type of weather, warm and dry in the summer, but cold and clear in the winter with temperatures sometimes far below zero. The Netherlands is a flat country and has often-breezy conditions, although more in the winter than in the summer, and more among the coastal areas than inland.

2.2 STATISTICS ON TEMPERATURE

Amount of precipitation (rain)	App. 760 mm/year
Number of days below 0 °C	App. 50-60 days/year
Number of days with snowfall [1]	App. 30 days/year
Number of days with freezing rain (black ice)	App. 1 day/year

[1]most of these days the amount of snow is not enough to cause serious traffic problems.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

The Dutch authorities are legally obliged to maintain their roads (care obligation as written in the road and civil code). Winter maintenance is part of this obligation.

RWS/Province-level (motorways, primary and regional roads)

RWS/Provinces use the uniform treatment times put up nationwide by CROW.

For national and regional highways and other roads up to a maximum speed of 80 km/h the following treatment times are used:

Pre salting:	2 or 3 hours;
Post salting:	2 hours;
Plowing/post salting:	1.5 hour .

Municipality-level (urban roads)

Municipalities often work by priority of roads. This is put down in a yearly-renewed plan, which is published to inform their inhabitants. First main-/bus routes are spread. Then roads, which enclose quarters and next roads within quarters are treated. Also important social locations like hospitals, schools, shopping centers, and the like, get priority.

There are no standards on manpower.

Equipment

RWS (DVS) has a framework contract for the delivery, installation, maintenance, etc. for demountable spreaders and snowplows. It's of great importance that all equipment works in wintertime. It should be available for 100%. So fixed times are used for reparations and if a machine cannot be fixed the supplier has to supply the authority with one of their own machines.

This framework contract describes:

- Requirements concerning construction and design standard's (EEG, NEN) of spreaders and plows;
- Requirements concerning placing the demountable spreaders on trucks;
- Requirements concerning spread rate, width, distribution, etc.;
- Requirements concerning drive;
- Requirements concerning liquid (brine) tank;
- Requirements concerning operation;
- Requirements concerning mounting the plow on a truck.

Material

RWS (DVS) also has a framework contract for the delivery of road salt (evaporated or rock salt). In this contract minimum requirements are placed, like:

- Composition of the product;
- Grain distribution;
- Presence of moisture;
- Presence of heavy metals;
- Delivery times.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Organization of the Dutch Ministry of Transport, Public Works and Water Management, concerning winter maintenance:

level 1:	Ministry of Transport, Public Works and Water Management;
level 2:	Rijkswaterstaat (RWS);
level 3:	Regional Direction;
level 4:	Highway Management Center;
level 5:	Operation Center.

RWS DVS is the Center for Transport and Navigation of RWS. Concerning winter maintenance, RWS DVS is responsible for:

- The development of RWIS's, consultancy and research concerning winter maintenance (de-icing materials, equipment and methods);
- Central tendering for equipment and road salt;
- Communication about winter maintenance together with traffic information center;
- Coordination in case of calamities (lack of salt; employing of 3 snow blowers/cutters);

The DVS also facilitates the purchase of winter maintenance equipment and does write/provide the „Guideline Winter Maintenance RWS" and consults the Ministry and local management centers.

The local management centers are responsible for operational (winter) maintenance. They consult the RWIS and other weather information sources and decide to start a run (winter maintenance action).

Road Weather Information System

Since the 70's RWS DVS has been experimenting with the RWIS. Traffic safety, cost reductions and a more limited use of salt have been the main starting-points of these experiments. Starting in the end of the 80's, The Netherlands (RWS and Provinces) has placed the RWIS on their roads and bridges (319 measuring stations in the year 2009).

Within winter maintenance the role of the weather bureaus is important, because in the RWIS only a few persons (winter maintenance coordinators) are detached to the winter maintenance night watch. The coordinator has access to weather precipitation radar-image, which is very useful in case of precipitation conditions. Actual local weather-reports for the coordinator specially focused on winter maintenance are accessible. A meteorologist of a weather bureau can be consulted by phone 24 hours and 7 days a week (only if contracted). A weather bureau makes an actual local prediction, which is presented by a user interface or sent to the coordinator by mail. The final decision is always made by the coordinator, based on meteorological predictions, precipitation radar, own experiences, contacts with coordinators from other districts and data of the RWIS.

The coordinator is at home (at night) and will be warned by the RWIS when slipperiness might be expected. Per highway management center a winter maintenance coordinator is stand by during one week (varies per highway management).

The RWIS station measures:

1. Air temperature and relative air humidity (1.5 meter above the earth surface);
2. Presence of precipitation;
3. Road surface temperature measured on the left (fast traffic and coldest) lane;
4. Sub-soil temperature measured under the asphalt layers of the left (fast traffic) lane;
5. Surface condition: dry, presence of moist and/or salty (passive sensors) measured on all lanes.

PART OF RWIS STATION AT THE ROADSIDE

The dew point is calculated from the measured values. Some measuring stations also measure wind speed and wind direction. On critical locations a camera is available for visual inspection of the road surface. The measuring stations are situated on locations which are critical under winter conditions.

These locations are not necessarily the coldest, but the combination of moist and low temperature makes the location critical for example roads through woods and near water. Also steel bridges can be critical especially at the start and in the end of the winter season. On most steel bridges a RWIS station is available. Distance between the stations is about 15 km (varies between 5 and 40 km).

In some situations measuring stations are used to start an automatically spraying action on bridges (using brine (NaCl) with a higher purity than the normal used brine).

For finding the most suitable location for a new measuring station, experience of road inspectors and thermal mapping are used.

The user interface is fully Web based and an access to the central server is possible from anywhere with a personal computer or laptop with Internet connection and Internet browser. Measuring stations are wireless (GPRS) linked to a central server. The central server takes care of a large number of functions. It manages the data communication with the measuring stations, and communicate real time with the winter maintenance coordinator. The RWIS send out alarms to the winter maintenance coordinators and can be seen in the user interface. Alarms can also be received on a pager, by voice mail or a mobile phone by SMS.

The information of the measuring stations is stored on the local measuring station for seven weeks. After seven weeks the data is stored for unlimited time on the central server.

When the coordinator is connected to the central server, the computer presents predictions of a weather bureau automatically in the user interface (only if contracted). The weather bureaus have access to the central server and use the actual and historical information of the measuring stations and actual weather information to have input for the predictions. The coordinator can use the output to make a decision.

The coordinator can also use the images of the user interface integrated weather radar (precipitation). It is also possible to consult a meteorologist of a weather bureau. Some weather bureaus offer a „total surveillance". Specialized meteorologists then guards an RWIS (receives alarms) and use the other actual weather information (models, precipitation radar, satellite pictures). When the situation exist that slipperiness is predicted or occurs, he or she will immediately warn the coordinator.

The collected data from the measuring stations are wireless (GPRS) retrieved by the central server.

When the winter maintenance coordinator decides to start a run (spreading- and/or plowing action), a process will start which will take several hours. The process contains:

Warning involved personal;

- Calling in equipment (commercial trucks from e.g., contractors). Demountable spreaders and salt (in barns) are stored on the property of the local surveillance centers;
- Inform neighborhood road managers;
- Inform police, VCNL (if this is done depends on the agreements).
- RWS-level (motorways and primary roads)

Communication between the different levels find place by phone or a message board, which is available in the user interface and accessible for participants in the RWIS.

The alarm coming from the RWIS is connected to a pager or mobile phone used by the winter maintenance coordinator. The time between the calling in the contractor and spreading the last square meter can differ (2 or 3 hours) depending the contract. This concerns a preventive spreading action.

Province-level (regional roads)

Also at Province-level winter maintenance is arranged per region by a winter maintenance coordinator. Most of them use RWIS in combination with meteorological reports and local knowledge of the area. When there is doubt, patrols are carried out.

Municipality-level (urban roads)

Municipalities do sometimes use information from regional weather bureaus like airports and consult meteorological services. Also inspections from local police are important. Sometimes the decisions are made together with the coordinator of the Province. Some of them use RWIS-data.

Equipment

The preparative program before winter activity consists of:

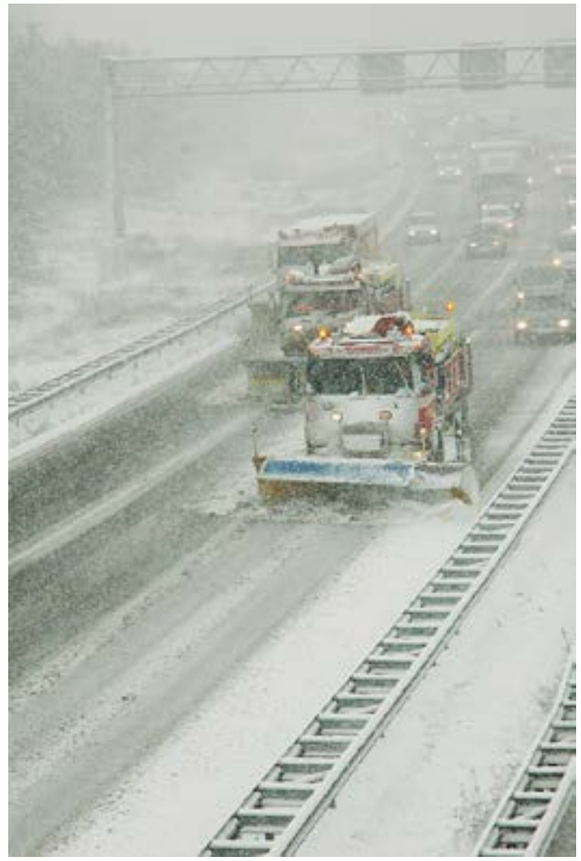
- Equipment checks (checklists and test protocols exist);
- Driver instructions, including test drives on the salt routes;
- Courses for winter maintenance personnel.

Prevention, for example, snow fences, is not used in The Netherlands. The only used prevention is precautionary treatment (preventive salting). The spreaders drive fixed routes (on the basis of: economics, safety, spreader ratio, etc.). Optimizing the salting routes is very complicated and is contracted to a specialized bureau. RWS has developed an application, called SOS (Salting Route Optimizing System), which is used.

A spreading management program is in use to have an optimized administration and to check if the contractor is doing his job well.

Municipalities in The Netherlands own approximately 2,000 spreaders and snowplows. About 30% of the spreaders are used for bicycle roads. The machines for bicycle roads have a capacity up to 1.5 cubic meters and are very often mounted on trailers. Municipalities mostly use their own traction and personal.

The provinces have for about 450 spreaders also in a wide range from 1 cubic meter for bicycle roads up to 9 cubic meters for regional roads. RWS owns circa 550 demountable spreaders (5, 7 or 9 cubic meters), about 850 plows and 3 snow blowers/cutters.



SPREADING-WIDTH IS 4-14 METERS.

In the Netherlands very often trucks of contractors are used to put on the spreaders and to build on the snowplows. Also the drivers on the trucks come from these contractors. RWS has agreements with contractors. These agreements lay down in a contract for several years (fixed for 3 years and possible to extend for 1 or 2 years). Most local districts have contracted one agent. This agent might have subcontractors. Per district there are several operational centers (2-4) depending on the road area to maintain. Per operational center several spreaders (6-12) and plows (12-18) are present.

The contractor gets a fixed price per season for all preventive spreading actions including a big check of all equipment before the start of the winter. Post salting is

done per hour. When the contractor does not react on a call-out, does not salt the route within a certain time period, if slipperiness occurs during the time the contractor actually had to spread salt and when the contractor cannot be reached at all high fines have to be paid.

Materials

In The Netherlands pre-wetted salt is mostly used (the wet component is sodium- or calcium chloride solution; as dry salt (NaCl) evaporated or rock salt is used). The wet component and dry salt are just before spreading mixed on the spreading disk and spread on the road. The ratio between dry salt/fluid is 2.5:1. Fluid means a 20%-NaCl-solution or a 16%-CaCl2-solution.

Properties NaCl

	rock salt	evaporated salt
NaCl amount	98.5%	99.9%
Grain size (80%) [mm}	0.8 – 3.15	0.20 - 0.45
Grain size (X50) [mm]	0.38	Grain size (max. <)
< 0.16 mm : 4 ± 1%	< 0.16 mm : 5%	Grain size (max. >)
> 3.15 mm : 5 ± 2%	> 1 mm :	1%
Anti-caking	75 ppm	75 ppm
Heavy metals	< 4 ppm	< 1 ppm
Unsolved parts	< 1.5%	< 0.01%
Moisture	0.3%	< 2.5%

These salts are according the specifications.

- Effectiveness: 12 kg ice per kg 100% pure sodium chloride (NaCl) at -5 ºC;
- Depression of freezing point temperature is - 7 ºC;
- NaCl (dry): summer price circa 46 Euro/ton; winter price about 54 euro/ton;
- Wet-component (16% CaCl2): Approximately 30 Euro/ton.

A tendency is going on to produce the wet-component out of dry salt (NaCl) already present in high volumes in the salt barns.

Salt is stored in barns. These barns are situated on the local surveillance centers or operation centers of RWS (opening of the barn is situated in the southeast direction). RWS has 61 barns with a total capacity of 59,500 tonnes. In last 10 winters an average amount of 68,000 tonnes per winter is used. It varied in between 25,000 and 124,000 tonnes.

In The Netherlands annually circa 36-38 runs are necessary. 75% of the actions are pre-salting (anti-icing) and 25% considers post-salting actions (de-icing)). Using these figures in combination with the road area to be spread the necessary storage facilities of salt can be calculated. For example, when the local highway agency maintain 260 km road lane (medium width of the road lane is 15 meters), 1,440 ton salt is necessary for one winter.

The local agencies can choose the amount of stored salt. An agency can choose to buy salt for the whole winter period or to have salt in storage for, e.g., 5 actions and to refill the barn after every action.

RWS DVS is responsible for the framework contract for salt. The storage capacity of the local surveillance centers is included in this contract. The contractor must be able to deliver a total amount of 3 times the storage capacity in one season (200% delivery guaranty in winter).

Provincial-level

The provinces are dealing with winter maintenance; the use of salt; the spreading actions and times within their road network should be treated in general in the same way as Rijkswaterstaat does.

Municipality-level (urban roads)

Mostly dry salt is used. The use of pre-wetted salt will be used more in the near future.

The RWS and Provincial personnel working with the RWIS, is educated by following an RWIS-course. There is no course for the truck drivers. They learn the job by experienced drivers.

Privatization

In The Netherlands operational winter maintenance on RWS-level is organized by the local highway management centers. Per highway management center one winter maintenance coordinator is in service during one or several week(s). Per highway management center about 3 – 5 coordinators are available. The coordinator uses the winter maintenance facilities and initiates the winter maintenance action when necessary. The decision for a spreading action stays at RWS. In case of preventive spreading no RWS personnel is involved anymore. In case of post salting personnel is available at the local center and for visual road inspections.

RWS only supplies demountable spreaders, snowplows and the salt. The trucks and drivers are contracted (see paragraph 2.4).

Getting information

RWIS

The RWIS contains actual and historical local information. The coordinator will be warned by the RWIS (pager, SMS) if slipperiness is expected in a couple of hours.

Meteorological

A prediction is presented in the user-interface of the RWIS. This information supports the coordinator by making a decision.

Precipitation Radar

The coordinator has access to images from the precipitation radar, which is integrated in the RWIS user interface or available on the internet site of a weather bureau. This is especially useful to start precautionary salting because of, for example, coming snow.

Meteorological information

Several times a day, meteorologists, working for the weather bureaus, make an actual local weather-report for the coordinator. This information is specially focused on winter maintenance in the region of the highway surveillance center.

Consults

It is possible to consult a meteorologist at a weather bureau by phone for 24 hours a day, 7 days a week. (only if contracted)

Patrols

Sometimes, if the coordinator thinks it is necessary visual inspections of road conditions are done.

Methods, equipment and materials for snow control

In The Netherlands heavy snowfall is very rare. Nevertheless, RWS can on demand use 3 snow blowers/cutters (Unimog U1750 or U2150 with Schmidt FS 5-Z snow blower/cutter). The snow blowers can also be used to remove large amounts of snow from the hard shoulder.

The concept of white roads does not exist, as prolonged snow on roads is unusual. In case of extreme slipperiness (icy conditions; black ice or snow) the policy can order to reduce the maximum driving speed to 50 km/h. Dynamic road signs show this information. When slippery occurs on porous asphalt roads, traffic can be concentrated on a single lane to have enough wheel passages, which keeps the salt on the surface. These regulations/guidelines are written in the Guideline Winter Maintenance RWS.

Methods, equipment and materials for ice control

Demountable spreaders are used. The driving speed on motorways is circa 70 km/h using pre-wetted salt and 40 km/h using dry salt.

Table 3.1 recommended average rate of spread

Type of slipperiness	Amount of NaCl (g/m2)	
	dry salt	pre-wetted salt
expected slipperiness (preventive spreading)	-	7 (1)
fog moisture	10	7
icing	15-20	7-10
glazed frost (2)	20	15
snow (after removal) (3)	20	-

(1) : On porous asphalt 14 g/m2 is used after a very wet period
(2) : When the glazed frost situations stays for several hours, 20-40 g/m2 dry salt should be used
(3) : Precautionary treatment: 15-20 g/m2 pre-wetted salt

Under specific weather conditions with a lot of salt on the road slipperiness can occur due to salt. It does happen very rarely. Three different kinds of appearances are known. If the problem occurs it can be solved by spraying brine (NaCl or CaCl2).

The equipment (demountable spreaders and plows) is stored at the local surveillance centers and operation centers. Also the salt barns are situated on these terrains.

Methods, equipment and materials for special problems

Porous asphalt will be, under some conditions, treated differently (see table 3.1). The road user will usually not feel or see any difference. Only, when the combi-

nation glazed frost & porous asphalt & minimal traffic occurs, it is possible that on the spots where there is a changeover from non-porous asphalt to porous asphalt, there is a difference in slipperiness. This can lead to dangerous situations.

Several bridges in The Netherlands are supplied with a fixed anti icing spray (brine) system connected to a RWIS. The highway management center (road manager) did choose this solution because of economic and safety reasons.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

Some spreaders are equipped with a GPS system. When the trucks return to the RWS terrain a printout of this system is made. This printout contains the route, the spread-width and the used amount of salt. This printout is used to evaluate the run. At the end of every winter season, a survey is done about salt-use, personnel, equipment etc.

3.4 TRAFFIC SAFETY AND INFORMATION

The information of drivers is given by the ANWB. The ANWB gets this information from the VCNL.

Ways of possible dissemination:

1] radio;

2] journals (radio and TV);

3] teletext;

4] telephone;

5] Internet.

Information on the roads (signs) is possible; if necessary a speed reduction is put on the signs. In worst cases lanes can be closed by putting a red cross on the road signs above the road lane.

Education/information to drivers about driving in winter conditions etc. is a task of the headquarters of RWS. Technical questions can be asked to RWS DVS.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

Co-operations between road operators and administrators

It's growing concern to uniform winter maintenance on different roads of different operators/administrators. On national level guidelines are made to categorize roads in means to treat them uniform.

There is also co-operation in the field of tendering. For instance one tender (4 provinces and RWS) is put on the market to buy salt. In several regions RWS and provinces together use a contract for the actual winter maintenance.

Training course personnel

In most contracts are put demands for capable personnel working in winter maintenance. Two courses are set up. One course especially for winter coordinators and another course for truck drivers of contractors or own organization. Content of last course consider aspects as: forms of slipperiness, using equipment (spreader and snowplow) and spreading management system, weather conditions, dosage of salt, driving aspects under winter conditions (slippery course), etc. In the end an exam is giving. In case of sufficient result, a driver is given a certificate, which allows him to do his job in winter maintenance.

Research on right decision spreading action

Matching information out of the RWIS and the spreading management system makes it possible to check if a decision for a spreading action was made in the right way. Background of this study is to support the coordinator in a better way, uniform the process to make a decision, save costs and environment.

RWIS

Research on several sensors of a road weather information system with the idea to diminish sensors in the road surface. Road sensors and the road itself need to be maintained. Under the severe Dutch traffic conditions a reduction of road works/closures is of great significance.

Also information out of the RWIS in combination with weather information is used to predict if every part of the spreading route has to be treated with the same amount of salt. It's research done under the name of "dynamic spreading".

Salt

Research is set up to measure the effectiveness of spreading different kind of salts on different kind of road surfaces for instance bicycle roads.

5 REFERENCES

Literature list

[1] : Standardization of Salt Spreaders

[2] : Preparation, Organization and execution of Winter Maintenance

[3] : Winter, Weather and Roads

[4] : Guideline Winter Maintenance Code RWS

Terminology

RWS: Ministry of Trsansport, Public Works and Water Management; Directorate-General of Public Works and Water Management. RWS is responsible for (winter) maintenance on all motorways and primary roads

DVS: Center for Transport and Navigation

Province: The Netherlands are divided in 12 provinces. A Province is responsible for (winter) maintenance on regional and local roads

Municipality: Is responsible for urban roads (town)

ANWB: Dutch Automobile Administration

VCNL: Traffic Information Center

RWIS: Road Weather Information System

CROW: Information and Technology Platform for Infrastructure, Traffic, Transport and Public Space

NEW ZEALAND Version 2014

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT COUNTRY

New Zealand (NZ) is an island country in the south-western Pacific Ocean comprising two main land masses, the North Island and South Island, and numerous smaller islands more notable being Stewart Island and the Chatham Islands. The total land area of the North and South Islands is 268,021 square kilometres.

The South Island is the largest land mass and is divided along its length by the Southern Alps with 18 peaks over 3000 metres the highest being 3,754 metres. The North Island is less mountainous but is marked by volcanism with the central North Island a highly active volcanic zone containing the highest mountain at 2797 metres.

The population is about 4.4 million of which 78% live in the North Island. Auckland is the most populous area with 1.4 million.

1.2 ROAD NETWORK & TRAFFIC

The NZ Transport Agency (NZTA) is a Government entity and has responsibility for a wide range of land transport issues including the management of the 10,895kms of State highway network. There are 73 City and District Councils responsible for 82,000kms of local roads the maintenance and construction of which are subsidised by the Government through NZTA. The State highway network carries 50% of all NZ traffic.

There are 19 billion vehicle kilometres travelled (VKT) on New Zealand state highways each year and 21 billion on local roads. State highways in the Auckland area carry 21% of the VKT.

All maintenance of State highways are procured

NORTH ISLAND STATE HIGHWAYS
(SOURCE NZTA)

through competitive tenders based on a variety of contract models covering specific geographic areas including alliancing, performance based, traditional and a hybrid of partial performance and traditional based. Currently, alliancing and performance based contracts are for 10 year periods and the others generally on a 3+1+1 basis. City and District Councils follow the same competitive procurement processes.

SOUTH ISLAND STATE HIGHWAYS
(SOURCE NZTA)

2 CLIMATE

2.1 OVERVIEW OF CLIMATE AREAS

NZ's climate varies from subtropical in the far north to cool temperate in the far south. The Southern Alps provide a barrier for prevailing westerly winds dividing the South Island into different climate regions with the west coast the wettest area and the east cost just over 100kms away is the driest.

The central North Island's volcanic plateau and the mountainous area of the South Island receive most of the snow fall in NZ. Snow rarely falls in the coastal areas although the east and south of the South Island may experience snow from time to time in winter. Frosts can occur anywhere in NZ with cold nights, clear skies and little wind.

New Zealand's temperate climate provides winter temperatures that do not generally remain below freezing during the day. This climate provides sometimes daily freeze/thaw cycles during the winter season with temperatures hovering around 0oC.

2.2 STATISTICS

The average winter temperature ranges from 10 to 15C (50 to 60F) and from 20 to 25C (68 to 77F) in summer. Temperatures rarely get above 35C or below -10C. The highest recorded temperature was 42C and the lowest -22C. Ground frosts mainly occur in the central North Island (about 70 days per year on average) and across the South Island ranging from 70 days per year on average in the coastal areas up to 150 days on average inland.

The weather is extremely variable and can provide 4 seasons in one day. The warmest months are December through to February and the coldest June to August.

2.3 WINTER INDEXES

A winter comparison through an indexing system is not undertaken in NZ. The NZTA defines three winter maintenance periods as:

1. high. (June, July, August and September where likely conditions are moderate to very severe),
2. marginal (May and October for light to severe conditions) and
3. low. (fine to light conditions)

with conditions catagorised into the following:

Fine:	no frost or ice
Light:	frost and/or light snow
Moderate:	freezing conditions after rain or snow
Severe:	continuous snow, packed ice
Very severe:	hard packed snow/ice with further snowfalls

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

The NZTA and Local Councils have a statutory obligation to take all sufficient precautions for the general safety of the public which extends to the requirement to identify potential hazards and remove them. Without having any specific references to winter services it is clear that removal of snow and ice hazards falls within these obligations. There are also specific powers given to close roads to execute repairs, remove obstructions or for the safety of road users.

The NZTA has developed levels of service for State highways

1A	Open to all vehicles	24 hour treatment
1B	Open with some restrictions e.g. chains	
2A	Open to all vehicles	Treatment 7am to 7pm. Pro-active treatment before 7 am if required
2B	Open with some restrictions e.g. chains	
3	Close road until able to make safe	

Where there is extreme snow or ice which closes highways a priority system based on the importance of the highway is used to manage treatment and apply resources.

Local roading authorities each have their own levels of service and maintenance strategies.

3.2 ORGANISATION AND OPERATION OF WINTER MAINTENANCE

Winter services for State highways are managed by the NZTA. City or District Councils are responsible for local roads within their territory. The NZTA is fully funded by Government for all roading matters and the Government provides financial assistance through the NZTA to all local roading authorities with the balance being met by the local population through property rates.

The NZ roading expenditure for maintenance and operations is $300 million for State highways and about $500 million for local roads.

The State highway network is managed on a Regional basis centered on Auckland, Hamilton, Wellington and Christchurch. These Regions are further subdivided into network areas for contract purposes.

Outsource Contracts

With the tendering of contracts for all types of maintenance work the NZTA sets the specified services, delivery and outcomes required including the levels of service. Winter services are included within the maintenance contracts.

For the central North Island and all of South Island where winter services are required the contract model currently uses consultant organisations to monitor and manage the operation of the networks with contractors carrying out the day to day physical works.

These contracts are currently based on a maximum 5 year term. The Contractors are required to provide all plant and equipment necessary to provide the levels of service required. This can vary from Region to Region depending on local requirements.

Included in contracts are local operational strategies for winter services which set out the management process, monitoring, treatment, emergency procedures and communication protocols in more detail.

These strategies determine the priority routes for treatment based on importance for the road user and the community it serves. Where adverse weather conditions may close highways the priority may change based on time taken to establish either the prime route or an alternative.

Following a significant review of state highway operations to achieve further efficiencies, the NZTA is moving to a system where suppliers of road maintenance services, including ice and snow management, are managed directly by the NZTA. The contract term is generally extended to nine years. The first such contracts are being let in 2013.

Ice Management

Due to environmental and public concerns, de-icing using salt was discontinued in the early 1980's leaving grit as the only treatment for ice conditions. In the mid 1990's calcium magnesium acetate (CMA) was introduced. This is now widely used on the highway network and for some local roads. Extensive monitoring of its application in various environments for over 10 years has shown that there have been no significant effects from the use of this chemical.

CMA is used in both solid and liquid form for anti-icing and de-icing situations. The NZTA purchases CMA each year based on historical usage and is distributed to Regional storage. Stocks are replenished through the winter if necessary. The main supply is in the form of 1 Tonne bags however a quantity of 25kg bags is purchased for distribution to outlying depots where handling equipment is not available.

CMA application rates will vary to suit the weather conditions and residual chemical on the road. Pre-treatment application rates range from 7.55mg/m^2 for light frosty conditions up to 30mg/m^2.

CMA is used in areas where there are a significant number of frosts or snow on major or significant routes.

GRIT SPREADER

LIQUID CMA SPREADER

SOLID CMA SPREADER

Abrasives or grit is also used either by itself or in conjunction with CMA. It is the main treatment on minor routes or roads with infrequent frosty conditions.

The contractors resources include purpose built plant for spreading grit and CMA.

Mixing equipment has been provided at the contractors main depots for preparing liquid CMA. A storage tank adjacent provides sufficient quantities when

CMA MIXING PLANT

required. This liquid chemical can also be transported in a tanker direct to where it is needed to refill the spreading trucks while on their treatment routes. Contractors are required to calibrate all spreaders prior to winter.

Snow Management

The main snow removal equipment used is a simple front-mounted truck plough to remove snow as far as possible followed by a rotary broom to clear remaining slush. CMA is used to break down any snow pack.

Treatment Monitoring

Contractors have been introducing GPS to their fleets and Automated Vehicle Location (AVL) is available via the internet. This system indicates when vehicles are spreading and captures the spread rates and locations and also when and where trucks are ploughing.

Road Weather Forecasting

The highways in central North Island and a large part of the South Island have been thermally mapped to provide spatial variations of road surface temperatures. The mapping also identified the varying climatic domains with 11 in the South Island and 6 in the central North Island.

In order to develop nation-wide road weather ice predication forecasting the establishment of a network of automatic road weather stations across the country was necessary. Identifying the climatic domains has allowed for the strategic positioning of these weather stations.

The NZTA decided not to build and own weather stations but to contract for the supply of the required information and weather data only. This national road weather service is now provided by the NZ Metservice which has installed the network of weather stations to deliver the information and data required.

Metservice provide forecasting including ice prediction and observation data for each climatic domain via the internet. Metservice provide their forecasts to Vaisala in the U.K.who in turn provide road surface temperature and road state forecasts through their Icebreak model back to Metservice.

The specific web site also brings together all publicly available weather information from Metservice such as radar, satellite images, charts, general weather forecasts and warnings issued in addition to observation data from many other weather stations managed by Metservice. This provides ready access to a wide range of weather information for road managers each day to plan their operations, treatment selection and treatment locations.

The objective is "just in time in the right place". This is critical to using CMA as the chemical is imported and relatively high cost and so must be carefully managed. The site also provides access to archived information for post event and seasonal analysis.

3.3 ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

Control measures are set out in the contract specification and in a regional specific operations strategy. It is expected that the contractor will be proactive in response to oncoming storms, with a requirement to monitor the weather using the forecasting system operated by the NZTA and confirming with the contract manager the management plan for the next 24 hours. For forecast large events, snow clearing plant is expected to be pre-positioned to maximize effectiveness and shorten response times.

The contractors' performance is then monitored through the GPS AVL system, by contact directly with the contractor during the event for updates and by on-site inspections. The contractors are required to maintain the road surface in a safe condition in accordance with the Levels of Service requirements. The success rate in predicting and applying treatment is to be at least 95%.

WEATHER STATION FORECAST AND OBSERVATIONS

The contractor is also required to submit records documenting all monitoring and activities carried out during an event. This includes printouts from the AVL system detailing for each vehicle their time and location when CMA, gritting or ploughing commenced and finished, the application rates and the quantity used. This is particularly valuable along with the road weather forecasting and observation data to support the decisions and to validate the performance requirements where Court enquiries are made as a result of crashes and fatalities on the road. The contract allows for auditing the contractors records in more detail if required.

3.4 AVALANCHE MANAGEMENT

State Highway 94, the highway into Milford Sound and a popular tourist route, is particularly susceptible to avalanches. In order to better manage the risk, and provide improved availability, an avalanche management programme was initiated in the early 1980's and has gradually been upgraded to a state where, today, it provides a world-recognised system to monitor snow conditions, predict likely avalanche conditions and locations, and precipitate controlled releases. Details can be found on the NZTA website.

3.5 TRAFFIC SAFETY AND INFORMATION

Contractors are required to erect temporary warning signs where road treatment is carried out. The NZTA operates a number of Variable Message Signs which are used where roads may be closed or restrictions to vehicles are in place advising motorists of alternative routes.

The NZTA also operates a 24 hour national call centre to receive reports from the public and Police about hazards on the road. This is recorded in a web based Traffic Road Event Information System (TREIS). The call centre then passes the information to the appropriate contact (usually the contractor) for attention. If the incident warrants public notification the event is marked accordingly in TREIS and the information is automatically sent to the NZTA public website.

The NZTA website also carries general weather warnings provided by Metservice specifically related to road weather. Once the event has cleared TREIS is updated which automatically updates the web site. The TREIS information is also directly available to others who wish to use the information such as the Automobile Association to include on their own road information web site and to provide traffic information through text or navigation systems.

4 ONGOING RESEARCH

Snow fences

Snow fences are used within ski field areas but have not been a feature on highways. A small scale trial is underway in the central North Island, although generally milder winters have not yet put the trial to the test.

Decision Guide

With the introduction of the road weather and ice prediction forecasting nationally, better decision making is expected on treatment selection both prior to and during an event. Decisions need to be made whether to apply chemical treatment prior to an event or during an event and at what application rates.

A Winter Service Decision Guide, which is a simple chart covering various temperature and weather scenarios with suggested treatments, is being tested and refined in operational conditions. The guide is incorporated within the best practice guides for the use of CMA. It may then be incorporated into the Metservice weather data and forecast delivery to automatically provide suggestions for frost, ice or snow pre-treatment when the appropriate triggers are met. The Guide also provides suggested treatment during snow events.

Performance and reporting

A simple matrix to record the decision made prior to and during an event together with the eventual observation is being trialed to provide a performance measure on the accuracy of the pre-event decisions. This will be personalized to those decision makers and will assist in determining success rates and training requirements. Again, generally milder winters have not yet provided a really testing environment to prove the value yet.

Comparing the forecast thermal map against the GPS recorded treatment sections will also provide a measure of performance.

NEW ZEALAND

Initial testing FAST

A fixed automatic spray treatment system using CMA was installed prior to the 2012 winter on a bridge deck in the central North Island. Minimal testing has been undertaken so far..

Geofencing

Using GPS/AVL together with ice prediction and maintenance decision guidelines the use of geofencing can be used to automatically control the placement and application rate of anti-icing chemical only to the sections of the road requiring treatment. Trial continues.

References

New Zealand Transport Agency
www.nzta.govt.nz

NZ Metservice
www.metservice.com

NORWAY

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

The Kingdom of Norway is a constitutional monarchy. Area of the Kingdom of Norway is 385,178 km2. Population was 5,3 million in May 2017. Monetary unit is Norwegian kroner (NOK). One Euro was 9,30 NOK in May 2017. Length of coastline is 25,148 km, including fjords. Largest lake Mjøsa is 362 km2. Highest mountain Galdhøpiggen is 2,469 m.

Much of Norway is mountainous. The western coast is gouged by deep fjords and dotted with islands along the coast. Norway is the country with longest coastline in Europe. The most important economic factor is oil-related activity.

Norway's administrative units are the Regjering (government) and Storting (parliament) with elections every 4 years. There are 19 counties and 426 municipalities. The latitude of the capital Oslo is 60° north.

1.2 ROAD NETWORK AND TRAFFIC

The categories of roads in Norway are the following:

Road type	Length of road
National roads	10 700 km
County roads	44 500 km
Municipality roads	39 400 km
Total public roads	94 600 km
Private, forest, farm roads	97 000 km

In addition, Norway have 10 000 km public pedestrian and cycle tracks.

All national roads are paved. In the other types there are a lot of unpaved roads. There are 3,2 million vehicles including 2,7 million passenger cars.

Nine-tenths of the country's area is located north

of 60º latitude, where there is heavy snowfall six months of the year. Winter road traffic (November through April) accounts for about 35% of the annual yearly traf-

fic volume. In Norway 20% of the maintenance budget is connected to the winter condition.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS, MAIN WINTER EVENTS TO BE MASTERED

The Gulf Stream makes the climate in Norway much milder than other parts of the world at the same latitude. The country rises with a mountainous area inside the coastline.

Norway experiences large climatic variations within short distances. In the lowland on the eastern part of the mountains the climate is drier with low temperatures down to –20 °C, occasionally down to -30 °C and -40 °C. While the winter temperatures will vary around 0 °C along the coast, and rarely below –10 °C.

In the western part of the mountains there is a lot of snow and wind, and often extremely difficult conditions for winter maintenance. There is a lot of precipitation along the coast, often as snow, and also a lot of wind. The moist climate along the sea creates a lot of problems with humidity freezing to black ice on the roads.

As an average in the south-eastern part of Norway there is 20-25 snowfalls during a winter. The number of snowfalls is much higher along the coast and especially in the north of Norway. In recent years problems with freezing rain and rain on frozen roads has become more frequent. The roads get extremely slippery and it is very difficult to handle for the road users. For the road operators it is also very difficult to handle as the rain very rapidly reduces the effect of the salt.

There are many snowstorms during winter in the mountains and especially in the north of Norway. On roads crossing the mountains, there are many road closures and periods were vehicles only can pass in convoy due to snowstorms.

2.2 STATISTICS ON TEMPERATURES, ICING, PRECIPITATIONS

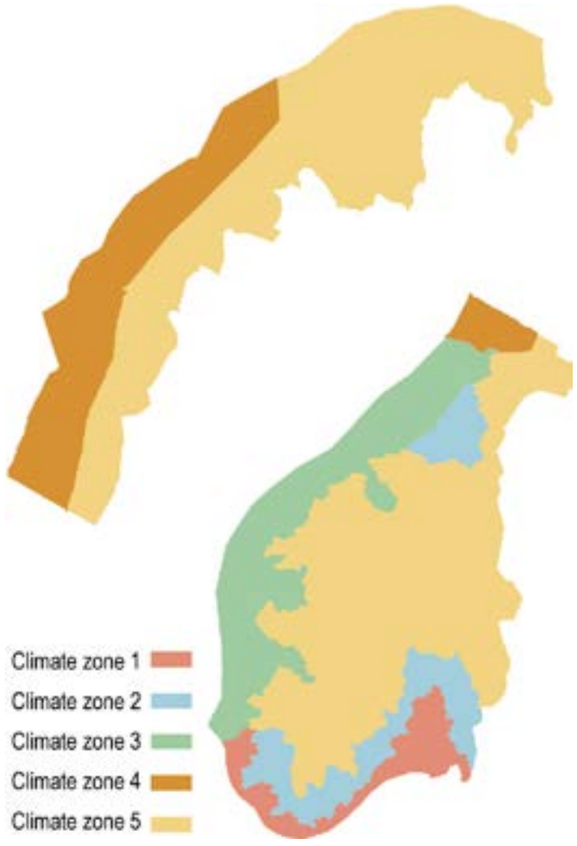
For winter maintenance purposes the country may be divided into five climatic zones, as shown in tables below.

Climatic Parameters in Different Climatic Zones

Climate-zones

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Length of winter, days	152	173	157	206	201
Snow-depth (cm)	41	55	41	63	72
Precipitation as snow (mm water)	158	225	258	332	248
Precipitation as rain (mm water)	830	734	1632	860	603
Mean temp. January °C	-3	-6	0.7	-3.3	-7.8
Mean temp. March °C	1.1	-1.4	2.6	-1.6	-3.3

2.3 WINTER INDEXES USED IN THE COUNTRY



A winter index system was established in 2003.

The index was a theoretical calculation of the need for winter maintenance operations. It was under testing, where the theoretical and actual numbers of actions were compared. Information about precipitation, wind, temperature variations around zero, humidity, etc. was collected from meteorological stations in the area. The computer then calculated the theoretical number of necessary winter maintenance actions based on the actual weather information. The conclusion from the tests was that the quality of the model was not good enough to be used for compensation of the payment for the winter contracts.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Legal obligation to perform winter maintenance?

According to the Norwegian Road Law the Ministry of Transport gives guidelines for maintenance of national roads and finances the maintenance of these roads. The Norwegian Public Roads Administration (NPRA) acts on behalf of the Ministry of Transport. NPRA also manages maintenance activities on county roads for the County Councils.

The municipalities finance and manage maintenance of the municipal roads.

Classification of the roads - Levels of service - Route optimization

The road classes are:

- National roads connect different part of the country, and also Norway to other countries and connect the different counties to important centers and are the main transport roads for goods and traffic within the country
- County roads brings traffic from the countryside to the national roads and county centers
- Municipal roads take care of traffic from the homes and businesses within towns and municipalities to the other roads
- Private roads include forest roads and farm roads.

Quality standards, performance indicators

Level of Service

The level of maintenance standards for national roads is described according to the importance of the roads and the annual average daily traffic flow. Traffic safety, traffic volume (average annual daily traffic (AADT)) and environmental effects are the parameters considered to make the most cost-efficient standard. The level of service for national roads in Norway is described in the maintenance manual, handbook R610 “Standard for Maintenance of National Roads”, dated 2014. The county roads and municipal roads have their own levels of service, but most of the county roads follow the national standard. Below is a translation of the main principles of handbook R610.

Purpose of winter maintenance

Winter maintenance should provide:

- Safe and accessible roads to the roads users during winter time with small impact to the environment
- Visibility, readability and function of road equipment, especially with regard to traffic flow quality, traffic safety and accessibility
- Clear visibility for all road users
- Accessibility to road equipment for maintenance personnel

Winter maintenance should shorten periods with adverse road conditions due to snow and ice on the road surface and secure adequate road grip and surface smoothness in periods when the road surface is covered with snow and ice.

Areas dedicated to pedestrians and cyclists should be passable and attractive to the users in a way that pedestrians and cyclists prefer to use the dedicated areas instead of using the roadway.

Maintenance cycle

Level of service for winter maintenance is described for a maintenance cycle related to the period before, during and after a weather event.

A weather event is defined as weather condition or a change in weather condition that affects and changes the winter road conditions. Weather events will primarily be related to precipitation, white frost, wind or temperature changes. Determination of when a weather event occur, should be based upon an assessment of the extent of changes in road condition compared to the necessary resource use for maintaining the road

	Maintenance cycle			
	Before weather event		During weather event	After weather event
	Steady state	Weather event alert		Clearing
Road condition	Approved road condition	Approved road condition	Accept of deviation from approved road condition	Reset of approved road condition within specified time limits
Activity	Monitor Maintain approved road condition	Monitor Maintain approved road condition Preventive efforts	Reduce deviation from accepted road condition Monitor	Re-establish approved road condition Monitor
Level of service	Approved road condition should be obtained	Approved road condition should be obtained	Deviation from approved road condition: Labour input at agreed level	Deviation from approved road condition: Labour input at agreed level until approved road condition is obtained.

condition specified in the standard (approved road condition). There should be available specified procedures for determining and warning of start and end of weather events.

Approved road condition defines the road condition that should be maintained in periods between weather events and that should be aimed at during weather events.

If the requirements set forward by the described approved road condition are satisfied on a road section, the requirements for labour input during weather event do not apply.

If the requirements set forward by the described approved road condition are not satisfied on a road section, the requirements for labour input during weather event do apply, and the winter maintenance resources should be in operation.

Winter maintenance classes

Winter maintenance should be carried out according to a classification of road sections in winter maintenance classes. The following winter maintenance classes are used:

Winter maintenance class	General specifications – approved road condition
WmA	Bare road surface– wet or dry
WmB	Bare road surface– wet or dry Compacted snow and ice surface between wheel tracks accepted during limited time periods
WmC	Bare road surface– wet or dry during mild weather - compacted snow and ice surface during cold periods
WmD	Compacted snow and ice surface
WmE	Compacted snow and ice surface Road friction down to 0.20 accepted

Classification of a road section is based primarily upon the traffic volume (AADT), as shown below.

Class	AADT			
	0 – 1500	1500 –5000	5000 –20000	20000 –
WmA				
WmB				
WmC				
WmD				
WmE				

The classification of road section into winter maintenance classes should, in addition to AADT, also take into account road category (national, regional, local route), traffic composition, public transport routes, road alignment and width, weather and climate, road accidents and environmental issues.

A continuous route should be maintained according to the same winter maintenance class for the whole route. Frequent changes in winter maintenance class should be avoided.

The transition between different winter maintenance classes should be located at places where the transition does not create difficulties for the road users. The winter maintenance routines at a transition should be performed with great care in order to minimize the effect of the change of standard to the road users.

The requirements for approved road condition, methods for friction improvement and required equipment resource input at weather event are given for each winter maintenance class in a format as described below.

Winter maintenance class WmA

Method for friction improvement	De-icing with chemicals, When de-icing is not possible, winter maintenance should be carried out according to special specifications.
Approved road condition	
Road condition	Bare road surface (wet or dry)
Friction - general	Bare road surface
Friction – special road sections	Bare road surface
Snow/ice-surface: Thickness Unevenness	According to special specifications if salt cannot be used due to weather situation
Resource input at weather event	
Maximal cycles-time for snow removal	1.5 hours
Maximal cycles-time for de-icing	1.5 hours
Time to re-establish approved road condition	AADT>6000: 2 hours AADT<6000: 4 hours

Winter maintenance class WmB

Method for friction improvement	De-icing with chemicals, When de -icing is not possible, sand should be used.
Approved road condition	
Road condition	Bare road surface– wet or dry in wheel tracks. Compacted snow and ice surface between wheel tracks accepted during limited time periods, loose snow less than 1 cm.
Friction - general	Higher than 0.25
Friction – special road sections	Higher than 0.30
Snow/ice-surface: Thickness Unevenness	Less than 2.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cycles-time for snow removal	2 hours
Maximal cycles-time for de-icing/ gritting	2 hours
Time to re-establish approved road condition	In wheel tracks: 2.5-5 hours Road as a whole: 1-5 days

Winter maintenance class WmC

Method for friction improvement	Sand De-icing chemicals during light snowfall or mild periods
Approved road condition	
Road condition	Bare road surface– wet or dry during mild weather - compacted snow and ice surface during cold periods, loose snow less than 2 cm
Friction - general	Higher than 0.25
Friction – special road sections	Higher than 0.30
Snow/ice-surface: Thickness Unevenness	Less than 2.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cyclus-time for snow removal	2.5 hours
Maximal cyclus-time for de-icing/ gritting	3 hours
Time to reestablish approved road condition	3 hours

Winter maintenance class WmD

Method for friction improvement	Sand De-icing chemicals on thin ice and white frost
Approved road condition	
Road condition	Compacted snow and ice surface, loose snow less than 2 cm
Friction - general	Higher than 0.25
Friction – special road sections	Higher than 0.30
Snow/ice-surface: Thickness Unevenness	Less than 3.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cycles-time for snow removal	3 hours
Maximal cycles-time for de-icing/ gritting	4 hours
Time to re-establish approved road condition	4 hours

Snow removal should be carried out on the road shoulder as well as in the road lanes, and close against road objects as guardrails, curb stones, etc. Accessibility and safety should be preserved in all crossings and bus stops along the road. Snow should not be placed in piles that reduce visibility.

During the thaw period, snow should be removed from ditches in order to allow free flowing of melting water.

In bus stops snow removal should maintain the standard height between roadway and area for passengers.

For bus stops and parking areas the requirement for bare road surface can be deviated from if the friction on snow and ice is maintained higher than 0.25.

Special requirements apply for road sections in high mountain areas.

Winter maintenance class WmE

Method for friction improvement	Sand De-icing chemicals on thin ice and white frost
Approved road condition	
Road condition	Compacted snow and ice surface, loose snow less than 3 cm
Friction - general	Higher than 0.20
Friction – special road sections	Higher than 0.25
Snow/ice-surface: Thickness Unevenness	Less than 3.0 cm Less than 1.5 cm
Resource input at weather event	
Maximal cycles-time for snow removal	3 hours
Maximal cycles-time for de-icing/ gritting	4 hours
Time to re-establish approved road condition	4 hours

Areas for pedestrians and cyclists

Winter maintenance should be carried out according to a classification of the area in winter maintenance classes. The following winter maintenance classes are used:

Winter maintenance class	General specifications – approved road condition
WmA-PC	Urban areas with many pedestrians and cyclists, main route for cyclists, areas specially equipped for people with disabilities
WmB-PC	Remaining area for pedestrians and cyclists

The requirements for approved road condition, methods for friction improvement and required equipment resource input at weather event are given for each winter maintenance class in a format as described below.

Winter maintenance class WmA-PC

Method for friction improvement	De-icing with chemicals, snow removal with sweeping or ploughing, when de-icing is not possible, sand should be used.
Approved road condition	
Road condition – day-time	Bare road surface (or snow/ice with max 1 cm loose snow when de-icing cannot be used)
Friction – night-time	Bare road surface (or friction higher than 0.30 snow when de-icing cannot be used)
Snow/ice-surface:	Unevenness less than 2 cm
Cross fall	As for bare road surface
Resource input at weather event	
Maximal cycles-time for snow removal	As for adjacent road, but not more than 2 hours
Maximal cycles-time for de-icing	As for adjacent road, but not more than 2 hours
Time to re-establish approved road condition	As for adjacent road, but not more than 2 hours

Winter maintenance class WmB-PC

Method for friction improvement	Sand De-icing with chemicals on areas with disability indicators
Approved road condition	
Road condition – day-time	Snow/ice surface with max 1 cm loose snow
Friction – night-time	Higher than 0.30
Snow/ice-surface:	Unevenness less than 2 cm
Cross fall	As for bare road surface
Resource input at weather event	
Maximal cycle-time for snow removal	As for adjacent road, but not more than 3 hours
Maximal cycle-time for de-icing	As for adjacent road, but not more than 3 hours
Time to re-establish approved road condition	As for adjacent road, but not more than 3 hours

Stairs, access ramps and platforms: Snow removal and de-icing/sanding should be carried out for the complete area.

The height of ice edges at area with ground heating should be less than 2 cm.

Winter maintenance during summer

Local plans for handling winter maintenance when winter weather events occur during summer should be developed and maintained.

The period between two winter seasons is categorized like this:

Winter season: Standby readiness
Reduced standby readiness
No standby readiness
Reduced standby readiness
Winter season: Standby readiness

The length of the periods with reduced standby readiness is defined according to local needs.

During the periods with reduced standby readiness there should be available at least one machine unit for snow removal and de-icing/sanding for each 100 km road. Higher requirements can apply according to local needs. Time to mobilize the machine unit during the periods with reduced standby readiness should be less than 5 hours.

Special winter works

Clearing after snow avalanche

Clearing and mending should be done as soon as it can be done safely.

Permanent repair should be done as soon as possible.

Special regulations connected to winter maintenance

De-icing products

Sodium chloride (NaCl) is used for chemical de-icing and is used where the approved road condition is "bare roads". Sand, gravel or crushed stones are used where the approved road condition is "snow/ice surface". The total amount of sand used for gritting the last five years has been between 540,000 and 870,000 ton per year. Salting has been used on the Norwegian road network since before 1970 and is used today on about 8 000 km of the highway network on Winter Maintenance Class A and B. Salt is also used in special cases on other roads to prevent thin ice and white frost. The last five years the total amount of salt used has been between 190,000 and 260,000 ton per year.

The contractors can use NaCl for salting of roads. Other types of salt can only be used after approval by the NPRA.

Studded tyres

Studded tyres were until the late 1990's commonly used. However, that has changed due to improved friction measures, better effects of non-studded tyres and for environmental reasons. In Norway today about 50% of the vehicles in average are using studded tyres. The studded tyres create dust, and air pollution is measured throughout the day in several cities. These measurements are used to make local restrictions if necessary. In the largest cities no more than 20% of the vehicles are supposed to use studded tyres. The two largest cities have now non-studded tyres on 80-85% of the vehicles in the winter season. In some of the largest cities the users have to pay a tax for the use of studded tyres to ensure that not more than 20% of the vehicles use studded tyres.

During summer it is not allowed to use studded tyres, and users will be fined. There are no penalties for the use of summer tyres in winter. However, one will be penalized for not securing proper road-grip during the winter period. Winter speed limits have been tried out to reduce accident rates, and so far, it has given satisfactory results.

Working hours

There is a "law for the working environment" which gives allowed working hours and a "law for driving- and resting time" for professional drivers. The contractors have to obey to all the laws and if necessary apply for exceptions.

Winter maintenance equipment

There are no specific standards for winter maintenance equipment; they have to follow the standard rules and regulations for each type of equipment. If needed the contractors have to apply for exceptions for snowploughs and other equipment that are wider than the vehicle. The same goes for special headlight for trucks carrying snowplough. The maintenance vehicles have to use special warning light during operations, if they do not follow the traffic rules.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Organization of winter maintenance

The NPRA is responsible for;

- planning, construction, maintenance and operation of the national and county road networks;
- vehicle inspection and requirement;
- driver training and licensing.

The NPRA is under the leadership of the Directorate of Roads, which is an autonomous agency subordinated the Ministry of Transport and Communications. The NPRA encompasses 5 regional offices and 20 counties/ district offices. Since January 1, 2003, all construction, operation and maintenance of roads have been tendered and contracted after a competitive bidding procedure.

Cooperation with other levels of road management organization

For matters pertaining to national roads, the NPRA is under the direction of the Ministry of Transport. On those related to county roads, the Regional Roads Officer is subordinated the county legislature.

Operational management of winter maintenance

- The contractors are responsible for achievement of the maintenance standard and have to plan, inspect and take the necessary actions. The contractor cannot decide to close a road on his own. Roads can only be closed with the approval of the NPRA;
- The contractor must prepare and maintain a plan for winter operations. The plan should contain: Personnel, stand by teams, equipment, storing facilities, routes, prioritized roads, points of special attention, etc.;
- The contractors must keep a journal for all inspections and all enquiries received from the public. They should report each activity, all consumption of abrasives and salt and the number of ploughing kilometers;
- According to the contract, operators of snow ploughing and spreading equipment must have required competence and pass a theoretical test arranged by the NPRA.

Road closures and traffic restrictions

All trucks, trailers and buses are obliged to carry chains with them if there is a risk of slippery roads.

Roads crossing mountains may be temporarily closed during snowstorms. Sometimes the vehicles can only pass in a convoy between two snowplough trucks.

Some roads crossing mountains are closed during winter. They will be opened in May or June. Special equipment is needed to open a road that has been closed during winter. The layer of snow can be more than 4 meters thick. A special attachment for a snow cutter unit has been developed. The snow cutter is mounted on an excavator. The excavator has chains and can move on top of the snow and cut layer by layer. When the top of the snow can be reached from the road surface the unit will be shifted to a wheel loader for the last layers.

To open the closed mountain roads after winter, a road finding system based on GPS has been developed; it works very well. It replaces the poles that have been used up to now.

Avalanches are a big problem on many roads alongside the coast and in the north. They can be closed in periods with danger of avalanche. In some cases, NPRA provokes the avalanche by the use of dynamite. Contractors who are working on roads that are exposed to the danger of avalanches have to undergo special training given by NPRA.

Also some roads and bridges along the coast can be closed during storms. Some bridges are closed automatically when the wind reaches above a certain speed.

Road information provision method & system

Meteorological information

There is an agreement between the Norwegian Public Roads Administration (NPRA) and the Norwegian Meteorological Institute (met.no). Met.no provides NPRA with weather forecasts and climate data at a market value. It includes the following forecasts from met.no:

- Graphical prognoses for wind speed, wind direction, precipitation, air temperature, air pressure, dew point temperature and cloud cover
- Written forecasts
- Wind, temperature, and precipitation fields for ground level and 1,500 m above sea level;
- Weather radar images
- Satellite images
- Separate forecasts under special weather situations, like freezing rain

These products cover the whole country and are provided on a regular basis throughout the year.

The forecasts bought on a regular basis are spread to the internal users via NPRA intranet and presented in a web-application for external contractors.

The graphic forecasts, the written prediction and the meteorological fields are updated three times a day. The radar images and satellite images are updated every 15 minutes.

NPRA has approximately 300 road weather information stations spread throughout the country. Most stations have sensors for:

- Air temperature
- Relative humidity
- Precipitation
- Road surface temperature
- Picture

Some stations also have sensors for

- Road surface condition
- Wind direction
- Wind speed
- Long wave emission
- Salt concentration/freezing point
- Video

The thermal maps were used to locate difficult areas. This knowledge was used to determine where to locate RWIS. The RWIS are located at places the road gets slippery before other places; early black ice or early snowfall. There are a couple of stations in each maintenance district.

3.3 ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

There are several research and development projects every year. In 1991-1994 a nationwide study to examine the effect of road salting on traffic safety was conducted. The result showed that road salting reduces the number of police reported accidents by 20%. A study of the environmental effects of salt on the area surrounding the roads was carried out in the period 1992-1996.

Maintenance quality through inspection and control of contractors

The contractor must report to NPRA if he has not achieved the requirement in the maintenance standard. The NPRA takes random inspection to see if the contractor has fulfilled the contract. Snow and ice thickness on the road surface are measured and compared to the contract requirements. Friction is measured with special equipment that is calibrated for this purpose. The inspection will also focus on the contractor's use of his quality system. If the performance is not according to the specification, a deduction in payment as a penalty can be demanded. The size of the penalty will depend on if it is a repeated problem, how serious the problem is, does it represent a danger to the road users, and how much money has the contractor saved by not doing the work.

3.4 TRAFFIC SAFETY & INFORMATION

Information provision to the road user

There are 5 Traffic Control Centres in Norway, one in each region. Their main tasks are control and monitoring, decision support and traffic information. The Traffic Control Centres provide information three times daily to the media about road conditions and road closures in winter season. This information is also available on Internet and text TV. The national radio stations give traffic information every morning and evening. Drivers can call 175 by telephone to get updated information about the road condition for special warnings the RDS radio will inform drivers.

The local radio stations very often have programs with a traffic theme at times when there is a lot of traffic on the roads. They give information about the traffic situation on the main roads and play music and give other traffic related inputs. These programs are quite popular. They are on the air morning and evening on weekdays, Sunday evening and in connection with winter holidays and Easter.

Systems improving traffic safety

The NPRA is responsible both for maintenance and road safety. The Roads and Transport Department in NPRA is responsible for road planning, building and maintenance. The Road users and Vehicle Department is responsible for driving license and vehicle inspection. Together with the Traffic safety section they are responsible for investigating accidents and trying to reduce them. Assembling all these specialists on different aspects of traffic safety in one special Traffic Accident Investigating Group allows for the efficient improvement of traffic safety.

The cost connected to winter maintenance is roughly 20% of the maintenance budget for the country. It is more in the north. Winter maintenance has a great importance for traffic safety. Traffic safety has top priority. If the winter cost is higher than budgeted, money will be taken from summer activities to compensate.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENTZ

4.1 NEW TECHNOLOGY

The last years and also today several research projects are going on with the aim to study:

- improved methods of spreading sand heated with hot water
- new methods for better snow and slush removing
- the effects of salt and residual salt on roads
- effects of different salt types and salting methods
- effect of salt when low temperature and during snow fall
- methods and equipment for measurement of friction
- better use of ITS in winter maintenance and follow up system of maintenance contracts

- better road maintenance for pedestrians and cyclists

NPRA is cooperating with the University of Science and Technology in Trondheim to improve the knowledge of winter technic and the education in this field. The university has established a Winter Research Centre and built up a new winter laboratory dedicated to winter research.

4.2 TRANS-NATIONAL COOPERATION TO IMPROVE LEVELS OF SERVICE BETWEEN NEIGHBOURING COUNTRIES

The Nordic countries have similar road-, traffic- and climate conditions and are cooperating to benchmark and share knowledge about roads and traffic. The Nordic Road Association (NVF), which can be compared to PIARC, has put this into its system. They have an own group working with road maintenance, including winter maintenance.

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Nord-FoU is a part of this cooperation where the Nordic countries finance and perform development and research projects together.

Information about the projects and reports can be found on their web-site.

5 REFERENCES

More information about Norway can be found on: www.odin.dep.no

The URL to DNMIs web site is: www.met.no

More information about NVF can be found on: www.nvfnorden.org

More information about Nord-FoU can be found on: www.nordfou.org

POLAND

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Poland (Polish: Polska [ˈpolska] (listen)), officially the Republic of Poland (Polish: Rzeczpospolita Polska,[a] listen (help·info)), is a sovereign country in Central Europe. It is a unitary state divided into 16 administrative subdivisions, covering an area of 312,679 square kilometres (120,726 sq mi) with a mostly temperate climate. With a population of over 38.5 million people, Poland is the sixth most populous member state of the European Union. Poland's capital and largest city is Warsaw. Other cities include Kraków, Wro-

cław, Poznań, Gdańsk and Szczecin.

The establishment of a Polish state can be traced back to 966, when Mieszko I, ruler of a territory roughly coextensive with that of present-day

Poland, converted to Christianity. The Kingdom of Poland was founded in 1025, and in 1569 it cemented a longstanding political association with the Grand Duchy of Lithuania by signing the Union of Lublin. This union formed the Polish–Lithuanian Commonwealth, one of the largest (about 1 million km^2) and most populous countries of 16th and 17th century Europe with a uniquely liberal political system which declared Europe's first constitution.

Following the partitions of Poland at the end of the 18th century, Poland regained its independence in 1918 with the Treaty of Versailles. In September 1939, World War II started with the invasion of Poland by Nazi Germany, followed by the Soviet Union invading Poland in accordance with the Molotov–Ribbentrop Pact. More than six million of Poland's citizens died in the war. After World War II, the Polish People's Republic was established as a satellite state under Soviet influence. In the aftermath of the Revolutions of 1989, most notably through the emergence of the Solidarity movement, Poland established itself as a democratic republic.

Poland has the eighth largest and one of the most dynamic economies in the European Union, simultaneously achieving a very high rank on the Human Development Index. Additionally, the Polish Stock Exchange in Warsaw is the largest and most important in Central and Eastern Europe. Poland is a developed and democratic country, which maintains a high-income economy along with very high standards of living, life quality, safety, education and economic freedom. According to the World Bank, Poland has a leading school educational system in Europe. The country provides free university education, state-funded social security and a universal health care system for all citizens. Situated between Eastern and Western European cultures and coined by a changing history, Poland developed a rich cultural heritage, including numerous historical monuments and 15 UNESCO World Heritage Sites. It is visited by approximately 17.5 million tourists every year (2016), making it the 16th most visited country in the world. Poland is a member state of the European Union, the Schengen Area, the United Nations, NATO, and the OECD.

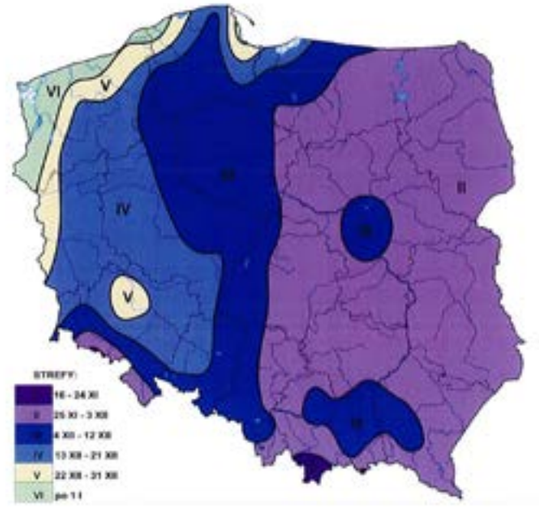
ZONE MAP FOR YEARS 1981-2010

ZONE MAP FOR YEARS 2001-2013

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The climate is mostly temperate throughout the country. The climate is oceanic in the north and west and becomes gradually warmer and continental towards the south and east. Summers are generally warm, with average temperatures between 18 and 30 °C (64.4 and 86.0 °F) depending on the region. Winters are rather cold, with average temperatures around 3 °C (37.4 °F) in the northwest and −6 °C (21 °F) in the northeast. Precipitation falls throughout the year, although, especially in the east; winter is drier than summer.



WINTER SEASON STARTING DATE ZONE MAP FOR YEARS 1981-2010.

The warmest region in Poland is Lower Silesia located in south-western Poland where temperatures in the summer average between 24 and 32 °C (75 and 90 °F) but can go as high as 34 to 39 °C (93.2 to 102.2 °F) on some days in the warmest month of July and August. The warmest cities in Poland are Tarnów, which is situated in Lesser Poland and Wrocław, which is located in Lower Silesia. The average temperatures in Wrocław are 20 °C (68 °F) in the summer and 0 °C (32.0 °F) in the winter, but Tarnów has the longest summer in all of Poland, which lasts for 115 days, from mid-May to mid-September. The coldest region of Poland is in the northeast in the Podlaskie Voivodeship near the border of Belarus and Lithuania. Usually the coldest city is Suwałki. The climate is affected by cold fronts which come from Scandinavia and Siberia. The average temperature in the winter in Podlaskie ranges from −6 to −4 °C (21 to 25 °F). The biggest impact of the oceanic climate is observed in Świnoujście and Baltic Sea seashore area from Police to Słupsk.

2.2 WINTER SEASON DEFINITION

Winter is the coldest season of the year. In a temperate zone in the northern hemisphere calendar winter lasts from December till February. Thermal winter is defined as a period of time when the average daily temperature falls below 0°C. This definition is the base of the calculations below.

Poland's geographic location and land formation have crucial meaning for the climate and weather conditions. There are oceanic and continental air masses that collide over Poland. Moreover, local geological condition such as hilly area in the south and Baltic Sea in the north shape the winter season that could either be mild with oceanic influence or rigid with continental impact.

Winter season in Poland divided into zones for the years: 1981-2010.

Zone number	Start dates	Winter length (in days)
I	16-20. 11	>110
II	21-25. 11	>100
III	26-30. 11	>90
IV	1-5. 12	>85
V	6-10. 12	75-90
VI	11-15 12	60-80
VII	16-20. 12	60-70
VIII	21-25. 12	50-60
IX	26-31. 12	45-50
X	1-5. 1	20-40
XI	6-10. 1	<20
XII	11-15. 1	<10
XIII	After 16. 1	

The map below shows Poland divided into 6 zones (I-VI) depending on when the first day of average daily temperature below 0°C occurred. In order to set up the 6 zones it was decided that the winter should start no later than in the first days of January for the last zone (zone VI).

Table A shows the first day when teperatures fall below 0°C which indicates the start of the winter season.

Zone number	Winter season starting date (median)	Winter season length (median)	First day of winter season (temperature below 0°C)
I	16.11	127	4.10
II	25.11	94	1.10
III	4.12	77	15.10
IV	13.12	70	14.10
V	22.12	55	18.10
VI	1.1	32	1.11

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Legal obligation to perform winter maintenance?

According to the Polish law the guidelines for maintenance of national roads and finances the maintenance of these roads are covered in the General Director's of GDDKiA directives.

Winter maintenance standards

GDDKiA maintains more than 19 000 km of national roads (excluding the roads crossing some cities). The preparation phase starts in the July when most of the people enjoy summer holidays. Then the roads are carefully checked in terms of surface, shoulders and drainage system condition. If necessary partial renovation works are scheduled as well as general check-up is maintained. One of the crucial elements is drainage system that is always inspected meticulously. General check-up also requires to check the sides of the roads and the condition of the trees that may have weakened since the last winter. It is especially dangerous when there is heavy snowfall and the tree branches may not be able to hold the extensive amount of snow. So, road safety will be decreased.

The direct winter maintenance works that involve snow-removal and deicing are performed 24 hours a day, 7 days a week by the GDDKiA regional divisions.

Usually, the works are contracted to outside companies via public tenders procurements.

The winter maintenance works are directed by 104 area managers and 273 Road Teams. Their main tasks among many belong: preparing the snow removal equipment, collect all necessary materials that help prevent the icing of the roads, such as salt mixtures and specific abrasive materials essential for the winter maintenance works.

All together there are 2400 snow ploughs, approximately 1400 salt vehicles and other necessary equipment. GDDKiA has 286 salt mixtures storages that can store up to 430 000 tons of snow. On top of that GDDKiA sets up to 1 500 km of snow curtains.

In 2017/2018 winter season GDDKiA plans to use:

- 460 000 tons salt mixtures
- 3 500 tons calcium chloride
- 83 000 tons abrasive materials

The winter maintenance works during the 2017/2018 season on the national road network will be kept according to the following standards:

- standard I – road surface free of snow and ice in all widths along with shoulders, no snow and mud slides - approx. 5 000 km
- standard II - road surface free of snow and ice in all widths along with -shoulders - approx. 11 000 km
- standard III - road surface free of snow in all widths, de -icing of crossroads, crossroads with railroads, roads with more than 4% inclination, bus stops, other specified places - approx. 2 000 km
- standard V – roads free of snow, at least one lane with possible alternation, sprinkled when there is a possibility of road traffic - approx. 1 600 km

Winter maintenance plan assumes to cover particular routes under the same winter maintenance standard during the whole winter season. In case of long-term extreme weather conditions, including heavy snowfall and winds, snow storms, blizzards that will cause the snow removal impossible and winter maintenance difficult to keep up to standards there might be deviation from the rules.

24 hours/day road conditions information

GDDKiA established round-the-clock Road Information Points (PID) that collect the information relating to road conditions and convey it to road users and media. Information about road conditions are also on GDDKiA website, under the tab: driver's services. Road users may also use the GDDKiA hotline where they can obtain current road conditions information (hotline 19 111).

POLAND

On the other hand, GDDKiA uses the weather forecasts that allow to take some preventive actions such as salting the roads just before or shortly after the beginning of the snowfall on chosen road sections. For operational needs, there are 750 surveillance cameras and 500 meteorological stations installed. These devices provide the following data:

live video on national roads
temperature and humidity measurements
surface temperature
wind strength and velocity

Drivers tasks

The main task of the winter maintenance vehicles drivers is ensuring passage. The vehicles are broad, some of them take the whole lane's width and usually move slowly. They remove the snow, sprinkle it with salt thus ensuring a safer road and regular flow of the traffic. Even though the vehicles are equipped with yellow flashing service lights, they perform a crucial role, somewhat similar to that of police or fire fighters.

4 REFERENCES

More information about Poland's roads
www.gddkia.gov.pl

REPUBLIC OF KOREA

1. DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

FIGURE 1- POSITION OF THE REPUBLIC OF KOREA IN EAST ASIA

The Republic of Korea (called South Korea) is a medium-sized country, (100,221.78 km2) but quite densely populated (around 50.8million in April 2016) and located in East Asia next to Japan. The Korean Peninsula was divided into two countries, South and North Korea, since World War II and Korean War during 1950-1953.

The capital city of Seoul is also the country's largest city and chief industrial center. According to the 2015 census, Seoul had a population of 10 million inhabitants. The Seoul National Capital Area has 24.5 million inhabitants (about half of South Korea's entire population) making it the world's second largest metropolitan area.

The 2018 Winter Olympics, commonly known as Pyeongchang 2018 and marketed as „PyeongChang", is a major international multi-sport event scheduled to take place from 9 to 25 February 2018, in Pyeongchang, South Korea.

South Korea's "tiger economy" soared at an annual average of 10% for over 30 years in a period of rapid transformation called the "Miracle on the Han River". A long legacy of openness and focus in innovation made it successful. Today, it is the world's fifth largest exporter and seventh largest importer with the G20's largest budget surplus

1.2 ROAD NETWORK AND TRAFFIC

The road network comprises 4,193km of Expressways, 13,948 km of National Roads, 4,727 km of Special City Roads, 18,087 km of Regional Roads and 50,985 km of County Roads. All of the Expressways, National Roads and City Roads are paved with asphalt

FIGURE 2- EXPRESSWAY IN SOUTH KOREA

or cement concrete and approximately 92 % of Regional Roads and 86 % of County Roads are paved roads. Road transportation accounts for 90.6% of total freight transport. The total registered vehicles as of 2015 were 20.99 million.

Table 1- Road network (in 2015)

Area	Total	100,221 km2
Population	Total	50.8 million
Registed cars	Total	20.99 million
Length of roads	Total	107,527 km
	Expressways	4,193 km
	National roads	13,948 km
	City roads	4,727 km
	Regional roads	18,087 km
	County roads	50,985 km

2. CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

The Republic of Korea is a peninsula state which faces oceans on the east, south and west directions and is located in the northern hemisphere. The range of geographical latitudes is 33~39 degrees north. The topographical features are mostly, approximately 70%, mountainous except flat farming area in the southwestern region.

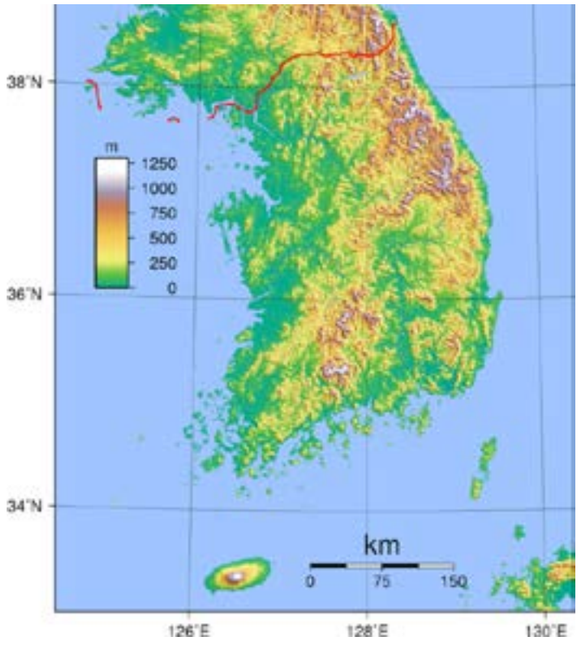


FIGURE 3- TOPOGRAPHY OF SOUTH KOREA

South Korea tends to have a humid continental climate and a humid subtropical climate, and is affected by the East Asian monsoon, with precipitation heavier in summer during a short rainy season called jangma , which begins around the end of June through the end of July. Winters can be extremely cold with the minimum temperature dropping below −20 °C (−4 °F) in the inland region of the country: in Seoul, the average January temperature range is −7 to 1 °C (19 to 34 °F), and the average August temperature range is 22 to 30 °C (72 to 86 °F). Winter temperatures are higher along the southern coast and considerably lower in the mountainous interior. Summer can be uncomfortably hot and humid, with temperatures exceeding 30 °C (86 °F) in most parts of the country. South Korea has four distinct seasons; spring, summer, autumn and winter. Spring usually lasts from late-March to early-May, summer from mid-May to early-September, autumn from mid-September to early-November, and winter from mid-November to mid-March.

2.2 Statistics on temperature and precipitation

The average air temperature is strongly dependent on seasons and the height above sea level. The annual average temperature over the country is 10~15ºC and the average temperature in the hottest summer season of August and the coldest season of January is 23~26ºC and -6~3ºC respectively. But the highest temperature during summer in the central lowlands area rises up to 35ºC and the lowest during winter in the high mountainous northeastern area falls below -30ºC.

The overall average temperatures in the country are shown in the Table. 2.

Table 2- Average Temperature (ºC)

Region	Winter	Spring (Autumn)	Summer
Central inlands	-6~4	4~13	22~26
Northeastern mountain	-11~-3	-1~8	17~20
Western coast	-5~7	3~13	20~25
Southern coast	-1~4	7~17	21~26

The annual precipitation is also markedly dependent on the height above sea level and the distance from the ocean. The annual average precipitation in most of the country is 1,000~1,500mm and that of the southern coast and islands area is 1,500~1,900mm. In relation to winter road maintenance, freezing or snowing period is relatively long and depends on region. Freezing period and snowing period in the whole country are 18~167days and 5~57days respectively. The detailed statistics of the annual average freezing and snowing days are shown in the Table 3.

Table 3- Average Annual Freezing and Snowing Periods / Depth

Region	Freezing period(-day)	Snowing period / cumulative depth
Central inlands	95~130	20~30days /55.3cm
Northeastern mountain	130~167	30~57days /178.2cm
Western coast	60~110	20~30days /44.7cm
Southern coast and islands	20~60	5~20days /16.8cm

2.3 WINTER INDEXES USED IN THE COUNTRY

There is not any special index or system to analyze and compare the road winter maintenance performances and costs. Each road managing organization performs its duty to maintain perfect road condition and serviceability based on winter maintenance regulations. The related regulations will be given in the following article.

The National Meteorological Office announces two type of winter events:

One is heavy snow, the other is cold wave.

Table 4- Type of winter events

Type	Warning	Advisory
Heavy	Snow	Above 5cm
(in 24 hours)	Above 15cm	(in 24 hours)
Cold	wave	Below -12ºC
(two days long)	Below -15ºC	(two days long)

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Winter maintenance of roads in the Republic of Korea is regulated by laws and regulations. The related laws are Road Law and Countermeasure Law against Natural Disasters. The roads are classified as Expressway, National Road, City Road, Regional Road, County Road or so based on the Road Law. The administrative road authorities based on the road classification are responsible for each level of road. The government established a state-run company, Korea Expressway Corporation (KEC), in 1969 and the KEC is responsible for all sort of things related to expressway design, construction, operation, management and maintenance in South Korea. Especially the KEC leads technological fields of road including winter service.

Each road authority operates, manages and maintains its roads according to the related regulations and specifications under the Countermeasure Law against Natural Disasters.

· Guideline of the road and level of service

According to the governmental guidance,

road authorities perform winter maintenances to meet following standards and specifications.

Table 5- Level of service for winter events

Grade	Los	Countryside	Urban
Level A (chemical & plow)	2hours	expressway Over 4lane road (above20,000veh/day)	City express -wayMain street
Level B (chemical& plow)	3hours	Over 4line road (under20,000veh/ day) 2lane road (above 5,000veh/ day)	the subsidiary main streets
Level C (plow)	5hours	2lane road (under 5,000veh/ day)	subsidiary roads
Level D	-	2lane road (under 500veh/ day)	etc

· Rules regarding type and characteristics of materials and equipment.

Until late in 1990s, most of road maintenance and management authorities had used natural sand, solid calcium chloride or mixed one even in the big city area.

In the meantime, Korea Expressway Corporation (KEC), a state-run company, introduced spreading method of pre-wetted sodium chloride with calcium chloride brine, 30 % of concentration, in 2000. And thereafter, the KEC uses only small quantities of sand on special sections of steep slope. The purpose of applying chemical agents is to melt down snow and ice and prevent freezing on the pavement surface. The KEC

has been a front runner to develop new technologies in the fields of road transportation. After that, most of road authorities and contractors follow KEC's winter maintenance strategy, applying sodium chloride, calcium chloride and/or with mixed brine as an anti-icing or deicing chemicals in Korea.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Republic of Korea is a quite densely populated country, and the economic activities of the people have been really active day and night. And so, the road authorities are absolutely responsible for maintaining their roads in good condition and open to traffic. We cannot imagine any closing of roads under any circumstances. In a winter situation, the road administrator eliminates or at least reduces problems in road serviceability according to the schedule set in the winter maintenance plan.

· Organization of winter maintenance

Road maintenance authorities are organized based on the level of roads. Each road authority is divided into many branch offices and each branch office is responsible for winter maintenance in its own road network.

Table 5- Organization of winter maintenance

Level of road	Responsible	authority maintenance offices	Staff members and equipment per office
Express way	Korea Expressway Corporation	53 branch offices	46 employees, 14 units of equipment (12 spreaders,1 wheel loader,2 backhoes)
National road	National road maintenance office	18 maintenance offices	33 employees, 31 units of equipment (24spreaders,1wheelloader,6 backhoes)
City road	City road maintenance office	7 special city maintenance offices	53 employees, 68 units of equipment (55 spreaders,2 wheel loaders,7 dump trucks,2 backhoes)
Regional road	Provincial office	9 provincial maintenance offices	50 employees, 56units of equipment (26 spreaders, 1 grader,24 dump trucks,5 backhoes)
County road	County office	155 Counties	18 employees, 11 units of equipment (9 spreaders,2 backhoes)

· Operational management of winter event

Figure 4- equipment for winter events

SALTS SPREADER

SNOW PLOW

SNOW BLOWER(1000T/H)

SNOW BLOWER(6000T/H)

Considering weather forecast and road condition, the road administrator shall make a decision to spread materials and/ or mobilize equipment on the roads. According to the governmental regulation, snow exceeding 3cm depth shall be removed by snow plow and applied by deicing chemicals on it.

Frost, ice, and snow up to 3cm of height shall be melted down or removed with the help of deicing chemicals and/or machineries. Some places on the steep slope section of the road, abrasives like sand, shall be additionally spread. We also distinguish just plowing, just spreading chemical materials or both activities carried out simultaneously based on road condition.

In the case of the Korea Expressway Corporation (KEC), each maintenance office covers 70~80 kms of expressway and operates 12 units of spreader truck

Figure 5- Equipment for winter events

AUTOMATIC SPRINKLING SYSTEM(BRINE)

FIGURE 6- ROAD SURFACE MONITORING SYSTEM

which is mounted with an accessory snow plow, 1 blower, 1 wheel loader, 2 backhoes, 1 calcium chloride brine manufacturing facility, and so on.

Each office especially operates several automatic calcium chloride brine sprinkling systems on the vulnerable sections such as interchange ramps and steep slopes. The sprinkling systems are automatically operated and controlled by smartphone and/or internet service.

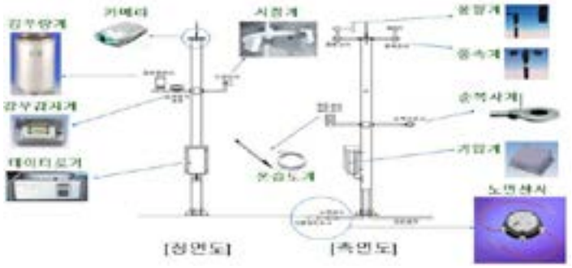


FIGURE 7- ROAD WEATHER MONITORING SYSTEM

Winter maintenance monitoring & control system

Each maintenance office operates monitoring system and controlled winter service equipment.

Road Weather Information System

There are over 100 road weather information stations in expressway.

3.3. ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES AND COSTS

We cannot use nationwide statistics of the snow and ice control measures. And so, we can use only the statistics on the melting materials here and you can estimate the cost of a year with the consumption of the snow melting material.

Table 6 – Snow melting materials (2015)

Road	Consumption (ton/year)			Consumption (ton/km)
	Total	NaCl	CaCl2	
Expressway (KEC)	206,329	174,986	30,143	49.2
National roads	136,874	109,923	24,281	9.8
City road (7special city)	82,286	45,439	36,829	17.4
Local authority	286,870	161,085	125,784	4.2

According to variable contract conditions in winter periods utilizing equipment for winter, maintenance show large differences as follows. All data is given for expressway and national road.

But city road and local authorities have different standards.

Table 7 – Equipment (2015)

Road	Winter service equipment		
	Total	Spreader	Loading equip
Expressway (KEC)	713	600	113
National roads	589	462	127
City road (7special city)	16,197	1470	14,727
Local authority	4,547	2821	1,726

3.4 TRAFFIC SAFETY AND INFORMATION

Road maintenance in winter season is an important thing, but providing road users with weather information and traffic information is more important to increase smoothness of driving and to prevent traffic accident.

Road authorities provide all sorts of information related to road situation to the users through mass media, internet service, smart phone, road auxiliary facilities and so on. Anyone who wants to travel somewhere can get all the necessary information using any of the above sources before his or her departure. Timely acquisition and analysis of the road information helps

the road users to choose a comfortable and safe route to travel in advance.

There are two kinds of communication means to transfer information. The first one is preliminary provision of information using the following tools.

Table 8 – Communication tools

Internet homepage	www.roadplus.com www.its.go.kr / www.utis.go.kr
Mass media	Local broadcasting station, TBN (Transportation Broadcasting)
Smartphone app	Expressway Transportation Information App., National road Transportation Information App.

The second one is the provision of real-time information on the road situation using road auxiliary facilities. The accessory facilities are Variable Message Signs(VMS), signboard and so on. Transportation control center provides real-time information about weather and road situation through the tools. Recognizing the real-time information, the road users can drive on the road without any difficulties. In total, 1,054 VMSs on the expressways and 580 VMSs on the national highways are respectively being operated in the Republic of Korea.

Road information provision method and system

Road authorities provide all sorts of information including road condition, traffic information and weather information through SMS and road accessory facilities. Road users can get necessary information to travel anywhere and anytime through the above sources.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGY

Korea Expressway Corporation had tried to apply electro-thermal snow melting system under asphalt concrete pavement until the end of 1990s. However, a big budget was required to install and operate the system because it consumed excessive quantity of electric energy and the initial investment for installation was too expensive as well. After that, some researchers have tried to minimize the initial cost and operational cost of the system.

INTERNET SERVICE (ROAD CONDITION AND TRAFFIC INFORMATION)

SMS THROUGH CELL PHONE OR SMART PHONE (ROAD CONDITION)

APPLICATION FOR EXPRESSWAY TRAFFIC INFORMATION

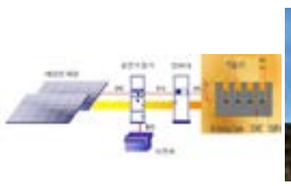
VMS (ON THE ROAD)

Nowadays, the solar energy and geo-thermal energy will meet the needs. We are on the way to develop a new snow melting system using geo-thermal energy.

The KEC experimentally installed snow melting systems on the expressway pavement using geo-thermal energy in 2010 and using solar energy in 2011. The geo-thermal energy was more economical and useful between the two. Therefore, the KEC is trying to develop a more useful energy for winter expressway maintenance.

4.2 NEW MANAGEMENT AND ORGANIZATIONAL APPROACHES

Each road authority prepares and uses its own winter service manual. According to the manual, the administrators and contractors perform their road management and control the quantities of materials based on temperature change and snow depth.



SOLAR ENERGY

GEO-THERMAL ENERGY

REPUBLIC OF KOREA

MONITORING DISPLAY (MARWIS-UMB IN LUFFT)

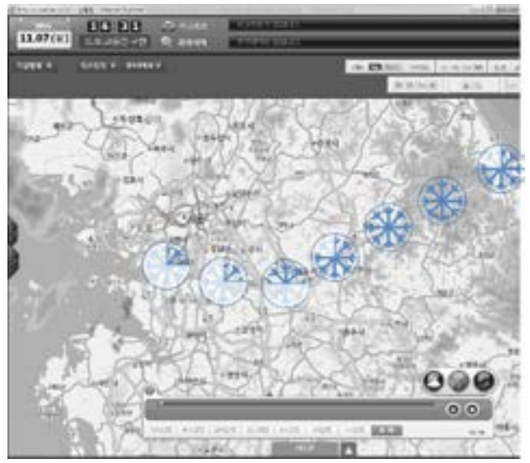
SURFACE DETECTING VEHICLE

Especially, snow melting chemical materials such as calcium chloride and sodium chloride have a severe effect on road facilities and the environment.

So, Expressway and Transportation Research Institute of the KEC is on the way to perform a research project to establish standard specifications for eco-friendly snow melting materials.

Road surface monitoring system

Prototype for the road surface detection of water, ice and snow as well as friction can be installed on vehicles with a distance of 1-2 meters between the measuring instrument and the object of measurement. This equipment delivers the following data: Road surface temperature, water film height, dew point temperature; road conditions: dry, moist, wet, snow, ice; ice percentage; friction; rel. humidity, air temperature.



Road surface icing prediction system

This system analyzes weather forecasts and displays the probability of the occurrence of freezing of highways, thereby playing a role in assisting the decision making function of road managers.

In addition, it provides road users with road surface information to assist drivers to drive more carefully in severe road conditions.

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1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Slovenia lies at the juncture of the Mediterranean, Alpine and Pannonian geographical areas as well as at the cross-point of the Roman, Germanic and Slavic language areas in Europe. Slovenia is a member of the EU from May 1, 2004. Since December 21, 2007, Slovenia has been a member of the Schengen area.

Its surface encompasses 20,273 km^2, 63% of which are covered by forests. Due to this, Slovenia is one of the countries in Europe with the most forests. 48% of its surface lies at an altitude higher than 500 m, which is characteristic for hilly areas.

Slovenia borders four countries: Italy (a 280-km border), Austria (a 330-km border) and Hungary (a 102-km border), all of which are members of the EU, and Croatia (a 670-km border).

In terms of political organization, Slovenia is a parliamentary republic. Its capital is Ljubljana. Currency in Slovenia from January 1, 2007 onwards EURO. In 2006, there were 2,008,500 inhabitants living in 5,996 agglomerations and 211 municipalities; 7.6% were farmers. Several nationalities live in Slovenia; however, most of the inhabitants are Slovenes (83.06%). There are two minorities in Slovenia: 0.32% of the total population is Hungarian and 0.11% is Italians.

The population density is 96.9 inhabitants/km2.

Economy: Gross National Product (GNP): 17,076 EURO/inhabitant

Slovenia's natural resources are well preserved. There are 144,509 hectares of protected areas and natural parks:

- the Triglav National Park with 84,805 hectares;
- 9 nature reserves with 1,515 hectares;
- 4 regional parks with 5,168 hectares;
- 10 natural monuments, and;
- 25 natural landscape monuments.

NATURA 2000 includes a 36% portion of Slovenia.

On 29 April 2004, the Government of the Republic of Slovenia determined, with the Decree on Special Protected Areas (Natura 2000 areas), which areas in Slovenia would be part of the Natura 2000.

286 areas were identified; 260 of them were determined on the basis of the Habitats Directive and 26 on the basis of the Birds Directive. These areas extend over 36% of the surface area of Slovenia. Forests grow on most of the areas; however, there are large areas without vegetation (mostly cliff walls), 9% of the areas are above the tree line; an important portion is also grassland.

The protected areas (the Triglav National Park, regional and landscape parks, reserves and natural monuments) constitute 25% of the total surface of the Natura 2000.

1.2 ROAD NETWORKS AND TRAFFIC

History of roads in Slovenia

Slovene transport routes developed some thousands of years ago due to Slovenia's geographical formations (Alpine, Pannonian and Mediterranean) as well as its location in the European region. Of course, man with his religious, social, economic and military tendencies played an important role in this development. Historical changes have affected the development of transportation routes.

As early as in the Stone Ages, the route from the Mediterranean along the Eastern Alps across the mountain threshold of Postojna and by the Ljubljansko barje moor in the direction of the Ptujsko polje flatland developed as the most convenient and direct longitudinal land transport axis, to which all transverse road routes have been connected. Later on, important long-distance trade routes led through Slovenia (Amber Road, Iron Route, Noricum Route and Salt Route); they complemented the road network and expanded it in new longitudinal and, especially, transverse directions.

In Roman times, the road network in this area was developed to a degree that satisfied the economic, commercial and military needs of the states which originated at later periods.

The medieval Slovene road network expanded on

the foundations of the Roman network; nevertheless, the roads had an especially international and transit character, for there was no big trade centers in those times in Slovenia. After the Habsburgs had gained access to the sea, roads were increasingly developed in the Karst area.

Contemporary roads

The public roads in Slovenia are managed by the state and municipalities. The total length of the roads (as of December 31, 2004) is:

CATEGORY OF ROAD	LENGTH (km)
Motorways	576
Expressways	617
Expressways – 2 lanes	15
Major roads	598
Regional roads	4,897
Total state roads	6,703
Local roads	13,814
Public tracks	18,245
Total municipal roads	32,059
Total public roads	38,762

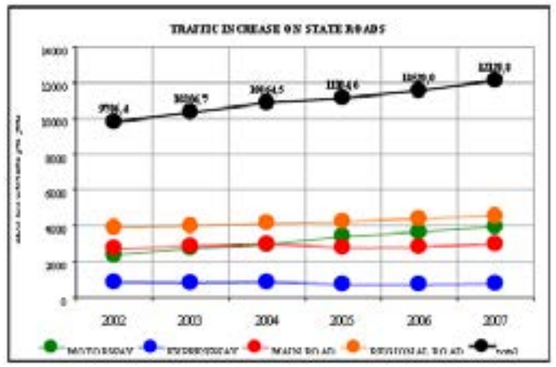
Besides the above-mentioned roads, the forestry service also manages 13,000 km of forest roads; these are, to a large extent, in public use.

Traffic loads on state roads

Traffic loads on Slovene roads are heavy, and they increase by around 3% per year. The biggest growth, i.e., 49%, was recorded in the 1992-1997 period.

The 2003 average daily traffic load on motorways was 22,616 motor vehicles per day. The portion of freight vehicles ranged from 10 to 20% on transit routes; the highest portion, namely 40%, was recorded on the routes in the direction to Hungary.

THE 2007 TRAFFIC LOAD MAP



The motorization level has come to 1.3 cars/ household

Registered motor vehicles

YEAR	TOTAL	CARS
2004	1,151 758	938,166
2005	1,204 242	964,781
2006	1,235 297	985,567
2007	1,286 903	1,020,127

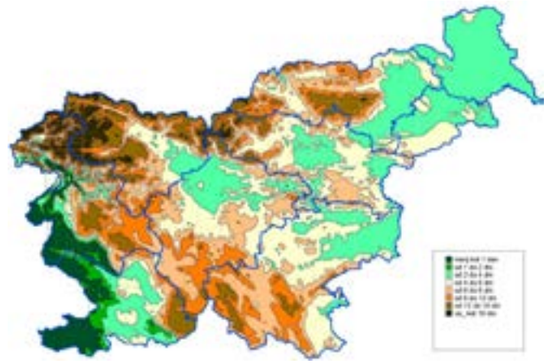
2 CLIMATE

The unequal dispersion of population and the resulting branching of the road network are the reasons for extensive daily migrations. Therefore, roads, especially those with heavy passenger traffic, have to remain passable during the winter time, even in the early hours of the day.

Because of Slovenia's position at the juncture of the Mediterranean, Alpine and Pannonian areas, its climate conditions vary significantly across the country; frequent daily and seasonal variations in temperatures and precipitation, causing variable road conditions, require from the road winter maintenance service frequent and quick response.

We can record substantial differences between the extreme western and eastern points of Slovenia, especially in the average number of days when the ground and roads are covered with snow.

There are two such days (snow cover) in Primorje (the Slovenian Littoral) per year and 45 days in Postojna, which is 30 km from the sea. There are 50 to 70 such days in the lowlands and more than 100 in the highlands. An important data for the winter service is the average annual number of days with more than 10 cm of new snow; there are 15 to 30 days of such snow in the areas of both mountain barriers and 10 to 15 such days in the lowland areas. Primorje has special characteristics because snowfall is very rare; nevertheless, gale force winds, and sometimes also snow drifts, cause traffic problems.



AVERAGE NUMBER OF DAYS OF SNOW-COVER DAYS

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

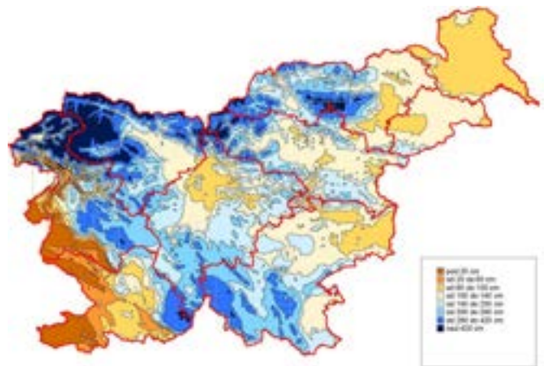
Classification of the roads

The process of ensuring the passability of roads is carried out in accordance with six priority classes concerning:

- The category;
- The density and structure of traffic;
- Geographic /climatic conditions and
- Local characteristics.

The passability of roads is ensured with regard to the priority classes:

Class 1: includes motorways and expressways, which must be passable 24 hours a day. When snowing, passability shall be ensured along the entire carriageway, as well as on important crossroads and access roads to larger car parks; however, emergency lanes also have to be passable. In the case of heavy snow, at least one carriage lane has to be passable, as well as access roads to larger car parks.



THICKNESS OF SNOW-COVER

Class 2: includes major roads, major urban roads and important regional roads. These roads have to be passable between 5 a.m. and 10 p.m.; when snowing, two-hour traffic delays are permissible between 10 p.m. and 5 a.m.

Class 3: includes the rest of regional roads, important local roads, urban feeder roads and local roads, which have to be passable between 5 a.m. and 10 p.m.; when snowing, two-hour traffic hold-ups are permissible between 10 p.m. and 5 a.m.

Class 4: includes the rest of the local roads, urban roads and suburban roads. As a rule, these roads have to be passable between 7 a.m. and 8 p.m.; however, when snowing, shorter traffic holds-up are permissible. In the case of heavy snow, one-day holds-up are possible as well.

Class 5: includes public tracks, car parks and cycle tracks, for which the passability is ensured on the basis of local needs. When snowing, one-day holds-up are permissible, and in the case of heavy snow, holds-up may last even longer.

Class 6: includes roads closed for traffic in winter conditions.

The exclusion of freight vehicles from traffic

In accordance with the provisions of the Order on Traffic Restrictions on Roads in the Republic of Slovenia, freight vehicles with trailers and vehicles carrying hazardous substances are prohibited from driving on all Slovenian roads, when snowing or blowing hard,

and they shall be excluded from traffic. On motorways and expressways, 25 locations in total are envisaged, at which vehicles are excluded from traffic; these locations have room for 950 freight vehicles; on other state roads, there are another 51 locations which can accept 1,990 freight vehicles. As a rule, these capacities are not sufficient, so occasionally, additional suitable areas are rented.

Rules regarding materials

The road gritting material, used in Slovenia, is sea salt (NaCl), and to a smaller extent also calcium chloride (CaCl2) and magnesium chloride (MgCl2). The latter is mainly used for preventive gritting on motorways, expressways and major roads, and whenever there are low temperatures (-8 0C). In the last few years, roads have been sprayed also with a saline solution. In this way, salt is prevented from being blown off from dry roads under heavy traffic conditions and the response time for ice melting is shortened.

Use in kg/m^2

	MIN	MAX	AVER.	CaCl2 portion
motorways	0.9	2.1	1.7	12%
other roads	0.6	1.85	1.34	0.6%

The average costs for winter maintenance in the last ten years (in millions of EUR):

	GRITTING MATERIAL	EQUIPMENT PERSONNEL
motorways	1.75	13.25
other roads	3.10	13.2

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

During the winter period, extending as a rule, from November 15 to March 15, roads are maintained in accordance with the winter service implementation program, which is prepared by the routine maintenance contractor, who submits it for acceptance to the specialist service at the latest by October 15th of the current year.

The winter service implementation Program includes:

- the organizational plan of management, competences and responsibilities of winter service operators;
- the schedule of preparatory works;
- the road network plan including the identification marks of priorities and starting points for the performance of winter services (road compounds);
- the allocation of machinery, equipment, gritting material and workers to implement the work planned;
- work crews on standby and available, level of preparedness and deployment schedules of work groups;
- snow removing plans and gritting plans for the prevention of ice formation;
- locations and methods of excluding particular kinds of vehicles from traffic in unfavorable road conditions;
- data collection methods and plan of informing the public on road conditions and passability.

The preparatory works are performed prior to the beginning of the winter period with the intention of ensuring efficient work of the winter road service. The works include in particular:

the preparation of machinery, traffic signaling devices and equipment, gritting material;

the preparation of roads and their surroundings (erection of supplementary signals at dangerous spots, placement of snow poles and other snow-drift protection devices);

training and professional education necessary for the performance of winter road service.

After the end of the winter period, it is necessary to remove the remains of gritting materials (sand), as well as the temporary supplementary traffic signals, temporary traffic equipment, road devices and facilities for the protection of roads and traffic in winter.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

For some years now, the costs of winter maintenance for state roads have been rising; they come up already to approximately 50% of the total maintenance costs. At the same time, the use of salt is questionable with respect to the damage it causes to vehicles as well as to the environment, road facilities and groundwater.

It is not possible to stop salting completely, for traffic safety would be impaired. Replacing salt with sand materials is uneconomical and inefficient in regard to contemporary traffic. The economic benefits of using salt are several times higher than the costs and damages it causes.

In order to protect the environment, only that much salt is used as necessary for traffic safety; salt gritting of roads has been reduced to the minimum.

Up-to-date technical equipment and regular education of all participants in the winter road service are crucial for rationalization. The attitude of the technical staff towards the problems of maintenance has had to be changed as well. Modern equipment is also critical to ensuring quality maintenance. Clearing and salting have been optimized. Users are also obliged by law to use winter equipment on their vehicles.

What to do in the future

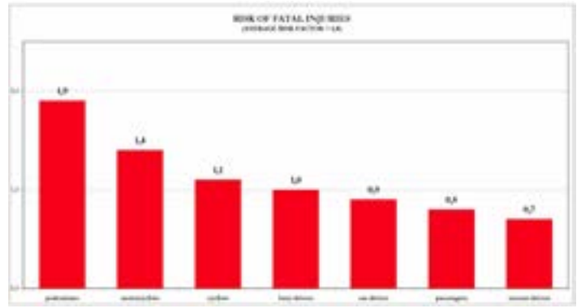
Analyses show that the fixed costs for road winter service, namely the costs for on-call and stand-by duty services, represent a large amount. To reduce these costs, a system is being introduced for monitoring road conditions at critical points and observing local weather conditions (road-weather station, video surveillance). It is being connected with the road-information system. Besides, up-to-date technical equipment is being introduced for calibrated dosing of gritting materials.

3.4 TRAFFIC SAFETY AND INFORMATION

Traffic safety

Traffic security in Slovenia is still not satisfactory. An analysis of the situation made for the needs of the preparation of the National Program for Road Traffic Security, showed that:

- 0.53% of fatal traffic accidents;
- 25.88% of traffic accidents with injures, and;



- 73.59% of traffic accidents with only material damage occurred during the 2007/2008 winter.

Road conditions and passability, as well as weather conditions and observing of regulations (e.g., on winter equipment for vehicles) exert a substantial impact on the occurrence of accidents and their increase in number.

Most of traffic accidents in winter occur in relatively good driving conditions; such accidents may end even with the worst results. These findings are based on the fact that most drivers are aware of the dangers of driving in winter conditions, but when conditions improve, they forget about the dangers and drive carelessly or even thoughtlessly.

The most frequent reason for traffic accidents in winter is improper speed, which is especially connected with favorable conditions on roads. The milder and drier the winters are, the bigger is the problem with speed.

The Ministry of Transport and, consequently road managers, are responsible for the below goals of the National Program for Road Traffic Security:

- Construction of the traffic infrastructure;
- Introducing measures to slow traffic down;
- Traffic education;
- Preventive measures and publicity actions;
- Surveillance.

Road users Information

During the time of winter maintenance, several methods of informing the public on road conditions are used:

- Radio and TV stations - in live;
- Telephone call to a specific number, directly via mobile appliances;
- Web pages of road managers and of the information

SLOVENIA

center of the Automobile Association of Slovenia;
- Traffic data are communicated also to ERIC (European Road Information Center) at its registered office in Geneva;
- Through information portals on the roads;
- INFO-pillars at the rest areas along motorways;
- Personal advice at information centers.

In accordance with the provisions of the Public Roads Act and regulations on the maintenance of public roads, the road maintenance company has to report regularly and in special circumstances on the conditions and passability of roads.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

With the purpose of improving road winter maintenance and environment protection, several researches and studies have been made, such as:
- Quick and efficient methods to control the quality of ice-melting substances;
- Checking the possibilities of excluding freight vehicles from traffic in the event of strong wind conditions;
- The introduction of weather-road stations into winter road maintenance;
- Determining the basic hydro-geological criteria for increasing the active protection of groundwater in the case of pollution on the Slovene road network;
- Effects of road gritting on the environment;
- An analysis of the winter service organization and operation.

A TRAFFIC–CAMERA PHOTO

The conclusions of the studies could be summarized as follows:
- too many gritting materials are used which have negative impacts on road structures, vehicles, groundwater, vegetation and the health of people;
- the pollution (especially of waters) can be substantially reduced by introducing special facilities;
- damage to road structures and facilities can be reduced with appropriate maintenance.

Therefore, the Slovene road managers have employed wet salting, which results in a reduced use of salting materials; the materials used are purer and of higher quality with the least harmful agents possible. By using up-to-date machinery, by monitoring and timely informing road users on road conditions, we endeavor to foster winter road maintenance rationalization and environment protection.

SPAIN Version 2014

1. DEMOGRAPHICS AND ROADS

Spain is a Southern European country located in the Iberian Peninsula. Its territory extends over 505,954 km2, bound in the North by the Bay of Biscay and the Pyrenees (which cover the border between Spain and France), in the East by the Mediterranean and in the West by Portugal and the Atlantic. The Straits of Gibraltar are Spain's southernmost boundary and constitute the point of greatest proximity between the continents of Europe and Africa (14 km). The country's population numbered 46.8 million in 2011, representing a density of 92 inhabitants per square kilometer.

SPAIN'S ROAD NETWORK (MAIN ROADS)

One salient topographic feature of the Spanish Mainland is a great central massif, known as the Castilian Plateau, covering virtually 50% of the country and which stands at considerable elevation. This plateau is not only one of the reasons why Spain features the 2nd highest average altitude above sea level (660 masl) in Europe, but also the reason why country's relief features a significant East/West tilt. The waters of the Spanish Peninsula flow at different volumes into the three seas surrounding the country owing to the fact that the climate and, above all, the orographical features influence the distribution and importance of the hydrographical system, with the Atlantic receiving the largest inflow. The Plateau is subdivided into two sections by a central mountain range, in the vicinity of which a number of mountain fringes encircle it (except on the western side where the plateau tails gently off towards Portugal).

Administratively, Spain is a parliamentary monarchy, composed of seventeen so-called Autonomous Communities or Regions:

Andalucia	8.3
Aragon	1.3
Asturias	1.0
Balearic Islands	1.1
Canary Islands	2.1
Cantabria	0.6
Castile-La Mancha	2.0
Castile-Leon	2.5
Catalonia	7.2
Valencian Community	5.0
Extremadura	1.1
Galicia	2.7
Madrid	6.4
Murcia	1.5
Navarre	0.6
Basque Country	2.1
La Rioja	0.3
Ceuta	0.077
Melilla	0.078
TOTAL	**46.81**

POPULATION FIGURES OF THE 19 AUTONOMOUS COMMUNITIES (IN MILLIONS OF INHABITANTS. 2011 DATA)

This political arrangement is similar to an organization of federal states. Spain's regions boast an ample level of self-government involving legislative, budgetary, administrative and executive powers, guaranteed by the Central State to each Region through the corresponding statute of autonomy. Each Autonomous Community is in turn divided into one or more provinces, totaling 52 in all.

In administrative terms, the Spanish road network is organized under three different levels of authority: firstly, the State-run Road Network dependent on the Central Administration's Ministry for Public Works (Ministerio de Fomento), secondly the Regional-run Road Networks (run by Autonomous Communities); and, finally, the Road Networks run by County and Town Councils.

The State-run Road Network covers the national highways forming long-distance routes linking different regions. Regional Road Networks are regional in scope, as their name implies, while the road networks run by County and Town Councils are entirely local.

The different networks feature the following lengths of road, spit into high capacity roads (motorways, dual carriageways…) and normal to low capacity (single carriageways, smaller roads):

Spain: road network (2011)

State run network	High capacity roads	11.346 km
	Normal to low capacity roads	14.970 km
	TOTAL	**25.835 km (15.6%)**
Regionally and locally run network	High capacity roads	4.840 km
	Normal to low capacity roads	135.233 km
	TOTAL	**140.073 km (84.4%)**
Spanish Network	**TOTAL**	**165.907 km**

As can be seen above, the state run network is a small fraction of the total network, barely 15%. It does, however, carry a substantial portion of the actual traffic in Spain, especially when one looks at the heavy goods vehicle traffic (HGV):

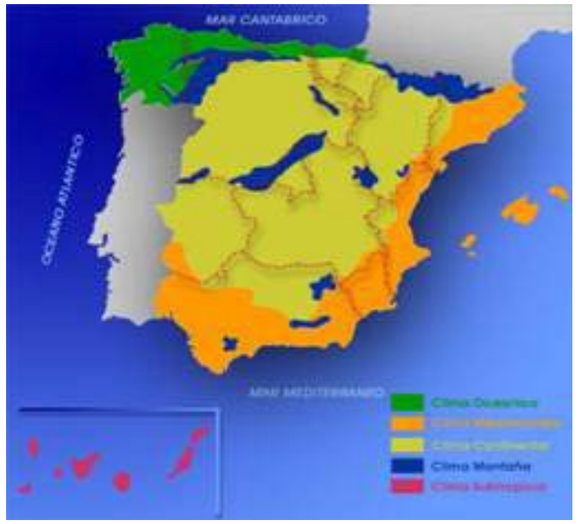
Spanish network: traffic (2011)

Total traffic	State run network	121.686.000 vehicles/km (51.8%)
	Regional and locally run roads	113.121.000 vehicles/km (48.2%)
	TOTAL	**234.807.000 vehicles/km**
HGV traffic	State run network	16.184.240 vehicles/km (62.7%)
	Regional and locally run roads	9630340 vehicles/km (37.3%)
	TOTAL	25.814.580 vehicles/km
Spanish Network	**TOTAL**	**165907 km**

2. CLIMATE

Broadly speaking, Spain features 4 main different types of climate:

- Atlantic Climate: Temperatures are mild all year long (average of 10 ºC to 20 ºC a year), the precipitation is abundant due to the influence of the humid air masses which come from the Atlantic. Galicia and the regions along the northern coasts belong to this zone.
- Continental Climate: Long and cold winters, and a mild summer in the north and warm in the south are characteristic of this climate (temperatures range from 25 ºC to -13 ºC). Precipitation is scarce and occurs during storms in the summer. The plain and the Ebro depression belong to this climate.
- Mediterranean climate: Temperatures are high in summer and mild in winter. Precipitation is irregular (especially in Almería and Murcia). The Mediterranean zone, Atlantic Andalucian zone, Baleares, Ceuta and Melilla are part of this climate zone.



- Mountain climate: Low temperatures with long and very cold winters, and short and warm summers. Precipitation is abundant and increases with altitude. The Pyrenees, Central and Penibético Ranges, some areas of the Cantabrica Range, Iberico Range and Grazalema are included in this zone.)

However, due to the complex geography, influence of different sea and oceans, the reality is substantially more complex, due to drastic variations in temperature and rainfall within those broadly drawn areas.

In fact, if we look at a more precise method of weather type classification, such as the Köppen scale, we can distinguish nine climate zones (see map below):

Firstly, we can distinguish two areas with extreme continental winter climate (the coldest month has an average temperature below -3 ºC, and the hottest over 10 ºC): on the one hand we have the Pyrenees mountainous zones, some spots in the Iberico Range and the Cantabrica Range, which barely have a dry season and, on the other hand, we have Pentibetico Range (Sierra Nevada) and some small areas in the Central Range which feature dry summers.

4 different zones feature warm, rainy climates (in which the coldest month has an average between 18 ºC and -3 ºC and the hottest over 10 ºC). Of these, an area covering most of Galicia, Asturias, Cantabria, Rioja, the north of Castilla y Leon, the north of Aragon and Cataluña, zones north of Aragon and the lower part of the Pyrenees Mountains in Cataluña and most of the Iberico Range feature no dry season and a warm summer. The area between the northern and southern borders of the Ebro depression, the interior of Girona and a zone to the south of the Iberico Range has no dry season either, but features hot summers. Some areas in Galicia, most of Ca-

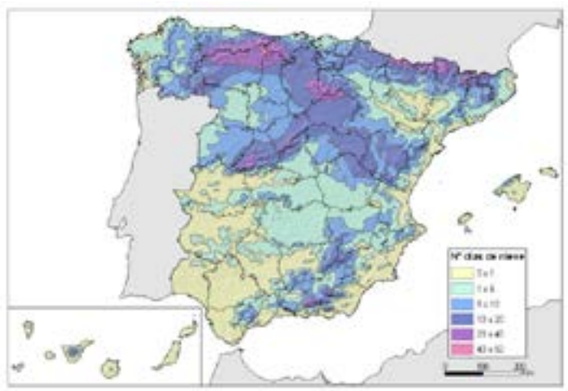
stilla y Leon and the Central Range, the southern border of the Central Range, the rest of the mountainous zones of the Penibetico Range and some regions of Cataluña are dry and with warm summers (outside of the mainland, the islands of Palma, Gomera, Hierro, most of the island of Tenerife, and the middle zone of Gran Canaria also fall in this cathegory). Lastly, southwest area of Castilla y Leon, Extremadura, most of Andalucia and Castilla la Mancha, Levante, the costal and lower mountainous area of Cataluña, the island of Menorca and most of Ibiza and Mallorca have a dry and hot summers.

Climatic areas defined as dry and warm (higher evaporation than precipitation and average yearly temperature below 18 º C) are found along the Ebro river depression, Castile La Mancha, most of the southeast peninsula and the southern parts of the islands of Mallorca and Ibiza. Areas in Almeria, Murcia, the interior of Gran Canaria, Fuenteventura and Lanzarote feature dry and hot climate (annual temperature average over 18 ºC). And finally, areas in Almeria, Murcia, and most of Fuenteventura and Lanzarote have a desert climate (evaporation greater than precipitation and a dry winter season).

Note: Other climate classifications exist that use a classification similar to the one used by the French, but they are not the official classification of the Climatological Atlas. The material distributed by the Education Ministry can be consulted, but that it isn't the system used by the AEMET.

Winter Weather

Winter weather can be harsh in Spain, with many areas displaying abundant days with sub-zero temperatures and snowy days. As can be seen in the map below, some areas in Spain average 40 to 50 days of snowfall in the reference period (1971 to 2000): areas of the Pyrenees, Cantabrica Range, Central Range, Iberico Range and Sierra Nevada Range. Around these zones extensive areas exist which feature an average of 20 to 40 days of snow per year. Areas of note in this zone would be the cities and surrounding areas of Soria, Burgos and Ávila and some of the major highways.



NUMBER OF DAYS WITH SNOWFALL

NUMBERS OF DAYS WITH TEMPERATURE ⩽ 0 º C
EDUCATION MINISTRY CAN BE CONSULTED, BUT THAT IT ISN'T THE SYSTEM USED BY THE AEMET.

With respect to the number of days which have below-freezing temperatures, the highest elevated zones of the Peninsula feature around 150 to 250 per year in the reference period (1971-2000). We can include Soria, Burgos, Avila, Teruel, Valladolid and Salamanca in the areas which have between 75 to 150 days of freezing temperatures. The areas of Leon, Segovia, Cuenca and Albacete and some major highways feature between 50 and 75 days of freezing temperatures. All in all, the three areas described above cover much of the surface of the peninsula, and a substantial part of the principal highway network has sections within all the areas previously noted.

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

The Directorate General for Roads which belong to Spain's Ministry for Public Works (Ministerio de Fomento) has powers extending to the technical and operational management of the infrastructure for the State-run Road Network. This service is headed by the Subdirectorate General for Operation and Maintenance.

The strategies for executing the winter maintenance work commissioned to the Maintenance Services are stated in documents known as Operating Plans. These plans are drawn up for each individual maintenance section and cover any scenario that is likely to occur, as well as the means required to tackle each one of them. The primary and desirable objective of these contingency plans is to limit the amount of traffic disruptions to, at a maximum, those assigned to the sector according to its assigned Standard of Service.

Three Standards of Service exist on the State-run Road Network, taking into account two parameters - the maximum number of traffic disruptions permitted to occur per year and their maximum duration.

Standard of Service 1 (SS1):

- all toll-free motorways and expressways;

conventional roads with an ADT of 5,000 vehicles and over, with the exception of mountain passes possessing alternative routes by motorway or expressways, assigned SL2;

- access routes to major skiing resorts;
- all provincial capitals and towns with a population of over 20,000 through which one of the State-run Network roads runs must be connected to the main -road network (assigned Service Level 1) by at least one SL1 road;
- both for this service leve1 and the next, SL2, an attempt will be made to provide the same service level on all road sections along the same route so that the level of service does not vary from origin to destination.

At this service level, blocking the road or cutting off circulation to all vehicles due to the existence of snow or ice on the road is not permitted. For this purpose, the actions to be taken will be cutting off circulation to heavy vehicles and restricting the passage to light vehicles with snow chains, when necessary, minimizing restriction time.

The maximum length of time for cutting off heavy weight vehicle traffic or restricting the circulation of light weight vehicles with snow chains will be for the duration of the snowfall plus 2 hours.

Clearing road margins must be done no later than 6 hours after the end of the snowfall.

Standard of Service 2 (SS2):

- conventional roads with an ADT ranking from 1,000 to 5,000 vehicles;
- all access routes to provincial capitals and towns with a population of over 20,000 are assigned at least SL2;
- all towns with a population of over 4,000 through which a State-run Network road runs must be connected to the main-road network (assigned Service Level 1) or to the secondary network (assigned Service Level 2) by at least one SL2 road.

For this service level, blocking the road and/or cutting off traffic to all vehicles will be admitted a maximum of 1 time annually. For this purpose, cutting off traffic circulation to heavy weight vehicles and restricting circulation to light weight ones with snow chains will be applied when needed, minimizing restriction time.

The maximum period of time for cutting off traffic to heavy weight vehicles or restricting it to light ones with snow chains, will be for the duration of the snowfall plus 4 hours.

Cleaning of roads margins must be done no later than a day after the end of the snowfall.

Standard of Service 3 (SS3):

- The remaining conventional roads, except for mountain passes bridging two provinces or comprising the only link between towns with a population of over 2,000 (which must be assigned at least SL2).

At this service level, disturbances caused by snow are allowed when, due to the intensity of the snowfall, it is necessary to take actions to assist the needs of the roads with a higher service level.

In no case will the presence of ice on the road that causes traffic disturbances be admitted on the State Road Network.

The quality of service is based on the degree of compliance with the Operational Plan. Considering the service conditions established in the conservation contract, the performance of the contract is faulty when the established service levels are not reached in the dif-

ferent roads object of the contract.

Nor have any fixed rules been set in respect of the characteristics of the materials or equipment used as these characteristics are defined in each individual Operating Plan and are adapted to the particular features of each road section.

In general, for the execution of the works assigned to the maintenance of the winter road network, frontal shove snowplows, and in some cases, also side ones, with solid deicer, solid-humid or brine spreads are used. In some mountain areas dynamic snowplows are used. The most commonly used emulsifiers are sodium chloride (salt) and in some cases, mixed with calcium chloride. Nowadays, the most used treatments are brine deicers.

3.2. ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Winter maintenance on Spanish roads is the responsibility of the Road Maintenance Services belonging to the relevant road authority.

In approximately 40% of the Spanish road network, continued interventions are needed for the maintenance of the road network during the winter.

Public-Private partnership

Virtually all of the authorities responsible for roads outsource part of their maintenance tasks to private firms which carry out the maintenance work on the majority of the infrastructural elements involved, generally including winter maintenance tasks.

The road network of the state is currently divided into 160 maintenance sectors. The maintenance of these sectors is contracted with private companies, who tender publicly according to a Technical Specifications Document designed by the Ministry. The document specifies necessary human and material resources to carry out the maintenance contract and amongst which all the operations related to the winter road network are found.

On the State-run Road Network, management of the resources used to carry out the tasks required to maintain winter serviceability is defined in the so-called Operating Plans covering the procedures for action and the work system for all tasks related to each section's winter maintenance. The Plans are drawn up to comply with the instructions laid down in a Service Note issued by the Spanish Directorate General for Roads.

The Private Companies, in order to comply with the Operating Plans, are in charge of the turnouts and they also play a role in the intervention decision process. In some toll roads, in fact management is fully in the hands of private companies that have been granted concessions or franchises.

These Operating Plans are approved by the management team in charge of each contract, and are revised annually, tailored to the new needs that may have arisen and ready for implementation in the following winter season.

A significant part of this annual revision relates to the inclusion of the experiences deemed important for improving the service, such as the application of new technologies or specific improvements to the work techniques employed.

The Operating Plans for each section must at least cover the following information:

- Personnel and machines assigned to the section (snow-clearing trucks, self-propelled snowplows and de-icer spreaders, etc.);
- De-icing agents (brine production plants, barns, silos and other storage facilities existing in the particular section and its vicinity, etc.);
- Policy and procedures for data transmission (communication systems between bases and vehicles, plus weather forecast and other types of data transmission);
- Organization of preventive tasks (established itineraries, schedules and inspections, etc.);
- Organization of corrective tasks (equipment location, itineraries, alternative routes, particular trouble spots and areas for parking vehicles, etc.).

Cooperation with Directorate for Traffic and for Civil Protection

Parts of the Operating Plans deal with coordination with other government agencies involved or affected by winter maintenance, namely the Directorate General for Traffic and the Directorate General for Civil Protection, both dependent on the Spanish Ministry of the Interior.

The Directorate General for Traffic plays an extremely important role in winter maintenance as its powers include traffic regulation on roads and motorist enforcement of the current regulations on vehicle circulation. Whenever roads are affected by snow and ice, this agency is responsible for enforcing the traffic restrictions imposed, such as the mandatory use of tyre chains or the mandatory stopping of a particular class of vehicles (eg. HGVs in heavy snow).

The decision to impose traffic restrictions (cut off traffic or use of snow chains) belongs to both the General Roads Directorate and the Department of Transportation. In case of traffic blocks, attention to affected users corresponds to Civil Protection Services.

To organize coordination between the different Government strata responsible for tasks deriving from the presence of snow on the roads, Provincial Protocols (based and adapted from National Protocols) are drafted. In them, the approach to be taken regarding the "Coordination of the General State Administration, in case of snowfalls and after extreme weather conditions that can affect the States National Roads network" is defined for each situation.

Road weather information

Information on weather forecasting is supplied by the Meteorology State Agency (AEMET) through the issuance of bulletins and a daily adverse weather prediction when snowfalls that exceed determined thresholds are expected.

The Directorate General for Traffic is installing an extensive weather station network in order to know the weather conditions on the roads. This weather information is transferred to motorists through variable message panels and is also available on the Internet.

3.3 TRAFFIC SAFETY AND INFORMATION

The Government Delegation or Sub-delegation in each province is responsible for providing information to motorists and the media in the event of snowy conditions.

Supplying Information to Motorists

The Directorate General for Traffic, dependent on the Ministry of the Interior, is responsible for keeping motorists and road users informed of road conditions.

At the present time motorists have different sources available for accessing information on the condition of roads:

Firstly, general information is broadcast on the different radio and TV stations operating and also published in the written press. secondly, real-time data specific to a particular road is put out by the Traffic Management Centers on variable message panels located on the actual roads. And finally, information can be provided verbally on the spot by officers of the Spanish Traffic Police Force (Guardia Civil de Tráfico) who, as well as regulating the movement of vehicles, set up controls to enforce the use of tyre chains in the event of bad weather conditions.

In addition, the Department of Transportation has established 4 levels that determine which is the degree of difficulty that a driver can find traveling on a particular stretch of road that is being affected by snow or ice.

- Green: Snow begins to flow. This color identifies a road stretch where it has started to snow and traffic is not affected. Speed recommendations are set (100 km/h on motorways and expressways and 80 km/h on other roads). The trucks must move in the right lane and cannot overtake other vehicles.
- Yellow: Some snow on the road. The road starts to cover with snow. Trucks are not permitted to circulate, and light weight vehicles and buses cannot exceed 60 km/h.
- Red: Road covered with snow. Circulation is only possible using snow chains and must not exceed 30 km/h. Circulation of trucks and buses is forbidden.
- Black: thick snow or ice on road. The road is impassable to all types of vehicles and there is a high risk of being immobilized for an indefinite period.

Systems for Enhancing Driving Safety

The improvement of driving safety on Spanish roads is built on two main pillars, managed by two different administrations. The first cornerstone is the maintenance and conservation of infrastructure, managed, by the Ministerio de Fomento (Ministry of Public Works). The second is the Traffic Management Authority, dependent on the Home Office, which supplies motorists with information on the state of roads affected by bad weather.

The information supplied is based on a obtaining and recording the parameters relating to meteorological conditions and the condition of the roads, modeling them and subsequently issuing the relevant information via the means quoted in the previous section.

Use of Sensors and Variable Message Panels

Knowledge of the state of a road affected by bad weather conditions is one of the activities under security via the agents commissioned to carry out maintenance and conservation tasks and members of the Traffic Police.

As from the year 2000, the first year weather parameter recording sensors (SEVAC) were installed on roads, their use has made it possible to know about, register, assess and model the capacity of the different weather parameters recorded, meaning that the actions carried out and their duration and purpose can be rated and confirmed.

In addition, information on the capacity, location and condition of the roads is publicized in the form of messages on the variable message panels. Almost 600 km of highways and expressways on the general road network plus a further few special kilometers on the regional network are covered by variable message panels.

Motorist Information Technologies

All types of technology are employed, whether based on audiovisual means, Internet or personalized receipt of facts via telephone calls and SMS text messaging. Ad -hoc information points are also available for particular spots on exceptional sections or routes.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGIES

As from the year 2000, all the machinery involved in winter maintenance work on the State-run Road Network has gradually been fitted with GPS locating systems which, connected to the control centers by mobile telephone, are used as an aid to fleet management for the snow-clearing machines. In addition to supplying real-time positioning of every vehicle, the system installed comprises several on board sensorsrelaying information on de-icer spreading and snow-clearing blade status in order to provide precise knowledge of the type of work each machine is performing. The data supplied by the GPS and the different sensors on board the vehicles are stored in a data base thus providing the possibility of creating a large range of reports on the tasks actually being carried out.. This system has proved to be extremely useful as it enables the actual porr weather episodes experienced to be studied and conclusions drawn with a view to improving the service provided.

In relation to the infrastructure, Fixed Automated Spray Technology (F.A.S.T.) has been installed as a system for preventing the formation of ice on some roads. The use of these systems has important advantages for those singular points (such as elevated structures) that are affected by extreme temperatures or humidity and require special attention. Today its major drawback is the high cost of deployment and maintenance.

4.2 NEW MANAGEMENT SYSTEMS

Winter maintenance management is reviewed after each season in order to correct any defects found in the preceding campaign and to propose improvements designed to provide a better service to motorists and road users during forthcoming winter seasons. In recent seasons, it has been proven that the effectiveness to avoid or reduce the number of stretches with traffic restrictions or delays and the length of these, is to block truck circulation in stretches that have difficulties due to heavy snowfall. These restrictions are carried out trying to stop trucks in the less time possible, intensifying the work of snowplows and obtaining better output during the clearing of the snow. Nowadays, the State Road Network is implementing a Plan for the construction of emergency car parks for heavy weight vehicles which considers the construction of 56 car parks where it will be possible to store these vehicles in case of road problems both during the winter season as well as during the rest of the year.

4.3 TRANS-NATIONAL COOPERATION

Spain participates in the SRTI Project which provides motorist information services, cooperation for cross-frontier traffic management and equipment for data exchange and traffic management, etc. in order to enhance safety and comfort and convenience on the roads linking Germany, France, Spain, Italy, Switzerland and Andorra.

5 REFERENCES

Data relating the climate has been provided by the Meteorology State Agency (AEMET) of the Ministry of Environmental and Rural and Marine Affairs.

1 Demographics and Roads

Area	Total	410,929 km² Mainly forest Fields 8%, Lakes and rivers 9%, Cities 3%
Population	Total	10 million
Road - Length - Vehicle km	Total trafficable by car	420,000 km
	Open to the public	210,000 km
	State Roads Including Motorways	98,500 km, 58 billion vehicle km 2,050 km
	State Cycle ways	2,200 km (uncertain)
	Municipal Roads	41,600 km, 24 billion vehicle km
	Municipal Cycle ways	11,000 km (uncertain)
	Private Road (Subsidies)	75,000 km
Number of vehicles	Private cars	4.3 million
	All road vehicles	4.8 million
Latitude (capital)	59 ° 20′ North	Sweden covers almost 55–70° N

2 CLIMATE

All statistical data is calculated from a 30-year period at the Swedish Meteorological and Hydrological Institute (SMHI). The years 1990-2005 have all been warmer than in the table. Through the countries elongated form in the direction north-south differs the temperature considerably in the southern compared to the northern parts.

The Gulf Stream makes it much warmer than in other parts of the world on the same latitudes (between 55° and 70° North). In southern Sweden the winter period is about four months and in northern Sweden about seven months.

SWEDEN DIVIDED IN FOUR CLIMATIC ZONES

The average number of days with frost per year (1961-1990) differs between 240 in the North West and 75 at the coast in the South.

	Average Temperature 1961-1990		
	Dec	Jan	Feb
Kiruna	-13.9	-15.6	-13.7
Luleå	-9.0	-11.5	-10.7
Östersund	-6.1	-8.6	-7.3
Stockholm	-1.0	-2.8	-3.0
Göteborg	0.8	-1.1	-1.2
Jönköping	-2.1	-3.7	-3.9
Malmö	1.3	-0.7	-0.6

	Average Precipitation (mm) 1961-1990			
	Dec	Jan	Feb	Cumulative snow fall depth
Kiruna	32	29	24	243
Luleå	42	40	28	233
Östersund	31	27	21	251
Stockholm	46	39	27	153
Göteborg	72	61	40	131
Jönköping	69	63	41	225
Malmö	58	49	30	113

Temperatures could increase by as much as 8 °C during winter months according to IPCCs RCP8,5 climate change scenario. In the north coastal areas, the increase could be one or some degrees more and in the south coastal areas one or some degrees less. The predicted changes are shown in the following figure.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Legal obligation

According to the Swedish constitution the Swedish Transport Administration (STA) is responsible for the road transports system and must work for attaining the objectives of the transport policy. The STA must especially work for securing that the road transport system is available, accessible and effective and that it contributes to the regional balance. The STA must also work for adapting and designing the road transport system according to high demands on environment and traffic safety. In one paragraph of the "Road Statute" it is stated that road operation includes the removal of snow and ice and taking actions against slipperiness to such a degree that the road is kept accessible to existing traffic, both vehicles and pedestrians.

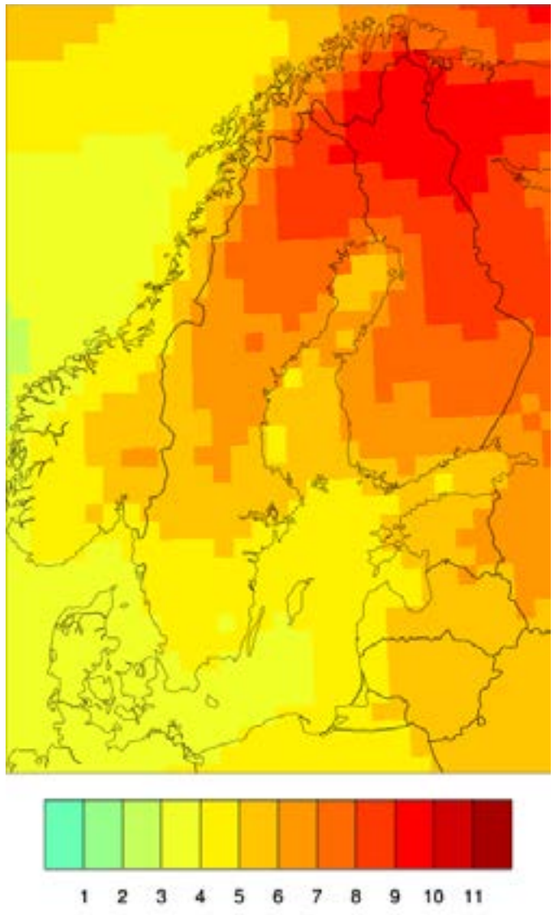
Classification of roads according to level of winter serviceability

The winter maintenance on the state roads in Sweden is carried out according to the "General technical description of road operation service levels during winter. Winter 2003" (VV Publ 2002:147 and 148).

DEFINITIONS

Roadside facility

A roadside facility refers to an auxiliary surface where a vehicle can be parked outside the roadway.



PREDICTED CHANGE IN AVERAGE WINTER TEMPERATURES FOR THE PERIOD 2071-2100 WHEN COMPARED WITH 1971-2000 (SMHI.SE).

Friction

The friction coefficient shall be determined in accordance with the SNRA Methods Specifications 110:2000, Friction Measurement on Winter Road Surfaces. (Retardation measurements with Coralba or similar).

Unevenness

The unevenness on thick ice or compacted snow roads shall be measured using a 60 cm long straightedge. This applies both in the longitudinal and transversal direction of the road as well as at an adjoining state road. The straightedge shall rest on two ridge points or between a ridge and the road surface, whereupon the measurement is taken at a right angle to the straightedge.

Snow depth

The snow depth shall be calculated as an average value on an area that is 1.0 x 1.0 meters. Every cm of slush is calculated as 2 cm of loose snow.

Materials De-icing/Anti-icing

NaCl (rock or sea salt) is the only salt used for de-icing/anti-icing. The NaCl should be 97% pure and must not contain more than 100 g of Potassium or Sodium Ferro Cyanide per tonne NaCl.

Crushed stone aggregate, usually of 2-6 mm fraction, has been used for several years.

On roads with speed limit above 70 km/h the maximum allowed aggregate grain size is 4 mm.

Crushed stone aggregate, 2 – 4 mm, is used for pedestrian and cycle paths. No addition of salt is needed.

The choice of standard classes for a certain road network is done according to the following recommendations given in the technical description:

STANDARD CLASSES

Traffic flow, AADT	Winter standard class
≥ 16,000	1
8,000 – 15,999	2
1,500– 7,999	3
500 – 1,499	4
< 500	5

Standard classes 1–3

Cross-sectional elements	Requirements during precipitation/Action time after precipitation				
	Trigger value		Action time in hours		
	Snowfall	Rain			
	Loose Snow depth (cm)	Friction (μ)	Standard class		
			1	2	3
Traffic lane	1	0.30	2	3	4
Side shoulder	1	0.25	4	6	8
Roadside facility	1	0.25	4	6	8

Cross-sectional elements	Dry weather requirements when action time after precipitation has expired		
	Road surface temperature		Evenness (cm)
	Warmer than -6 °C friction coefficient	-6 °C to -12 °C friction coefficient	colder than -12 °C friction coefficient
Traffic lane	Snow and ice-free	0.35	0.25	1.5
Side shoulder	0.25	0.25	0.25	1.5
Roadside facility	0.25	0.25	0.25	1.5

Standard classes 4–5

Cross-sectional element	Dry weather requirements when action time after precipitation has expired							
	Trigger value				Action Time			
	Loose Snow depth (cm)		Friction coeff. (μ)	Evenness (cm)	Snow depth/friction hours		Evenness hours	
	Standard class				Standard class		Standard class	
	4	5			4	5	4	5
Traffic lane	2	3	0.25	1.5	5	6	48	72
Roadside facility	2	3	0.25	1.5	8	8	48	72

Cross-sectional element	Requirements during precipitation/Action time after precipitation				
	Threshold value			Action time in hours	
	Snowfall		Rain		
	Loose Snow depth (cm)	Friction coeff. (μ)			
	Standard class			Standard class	
	4	5		4	5
Traffic lane	2	3	0.25	5	6
Roadside facility	2	4	0.25	8	8

"High" and "Normal" standard class for pedestrian and cycle paths and prioritized bus stops

Dry weather requirements when action time after precipitation has expired					
Trigger value		Action time/friction hours		Action time/evenness hours	
Friction	Evenness	Standard class		Standard class	
Friction coeff. (μ)	(cm)	High/P	Normal	High/P	Normal
0.30	1	1	2	2	4

Cross-sectional element	Requirements during precipitation/Action time after precipitation			
	Trigger value		Action time in hours	
	Snowfall	Rain		
	Loose Snow depth (cm)	Friction coeff. (μ)	Standard class	
			High/P	Normal
Traffic lane	2	0.30	2	4

A new strategy for reduced use of salt in winter road maintenance since 2004

Environmentally Adapted Winter Road Management shall ensure that the Swedish Transport Administration (STA) maintains high accessibility to the road network and traffic safety while minimizing the use of salt in winter road maintenance in a way that meets the demands of citizens and the business community. The strategy shall be compatible with prevailing environmental standards and STA's ambition to be an environmentally aware, efficient road manager that puts the customer first.

STA has worked actively for the last 30 years to limit the use of road salt in winter road maintenance. An investigative committee called "MINSALT" formed in the early 1990s a recommendation that:

- Roads with less than 1500 AADT should not be treated with salt, except during autumn and spring.
- Increased use of brine, especially for preventive actions.
- Improved weather forecasts.
- Improved equipment for snow removal and ice control.

Even if not all findings have been fully applied in all parts of the country the total salt consumption in Sweden may be considered low from an international perspective, but there is still reason to believe it can be further reduced. Examples of other actions taken over the years include physical protection of especially vulnerable water sources.

Objectives

Salt Consumption

The objective is to maintain high accessibility to the road network and traffic safety while minimizing the

use of salt. A salt index shall be used to measure accomplishment of the objective. During the 2006/2007 winter season and subsequent years, no operational area shall have an index greater than 1.0 (see 3.3).

Water

The objective is to reduce and eventually eliminate palpable negative impact from road salt on large water sources that supply more than 50 people.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

Organization

In 1991, the Swedish Government passed a decision that the design and construction of new roads, as well as all road operation and maintenance work within the state road transportation network, were to be contracted through competitive bidding. This entailed major changes at the STA. From having been a traditional central government agency, exercising the role of public authority while simultaneously carrying out construction and maintenance works in-house, the STA was to be divided into a client / contractor organization. In addition, it was stipulated that the contracting arm of the organization was to function like a private contractor, i.e., that it was to be subject to competitive terms on the open market and furthermore required to show a profit for its owner.

Requirements

Co-ordination

The contractor shall plan and co-ordinate his undertakings with those performed in the adjoining areas to ensure continuity in road surface conditions. Contact shall be made with contractors in adjacent areas to co-ordinate snow clearance and skid control measures.

Level of service

The requirements must always be fulfilled, except when weather conditions are so severe that it becomes impossible to meet the action time limits. The client (STA) shall be notified when such severe weather conditions prevail.

Operative actions

Sweeping and sand collection shall be carried out so that neither road users nor the surroundings are subjected to dust.

Forms of payment

Form of payment used at present is unit-price payment based on weather data statistics. In order to reduce salt consumption there is a bonus and fine system.

Finance

Twenty-five percent of the STA appropriation for road maintenance and operations, a total of almost SEK 1.8 billion (US$ 220 million), is spent on snow ploughing, skid control and other winter road maintenance works. Of this sum, approximately 50% are fixed costs, i.e., for stand-by, truck stations, storage facilities, etc.

There are 110 maintenance contract areas, covering the state roads, in Sweden. The maintenance contract areas comprise between 600 and 1,650 kilometres of road, centreline. This size has proven sufficient to be financially viable for contractors. In total here is 2,600 plough trucks contracted, which gives an average of 37.7 km per plough truck. In addition, there are graders and agricultural (farming) tractors used. Agricultural tractors are used mainly in pedestrian and cycle paths.

Competitive situation

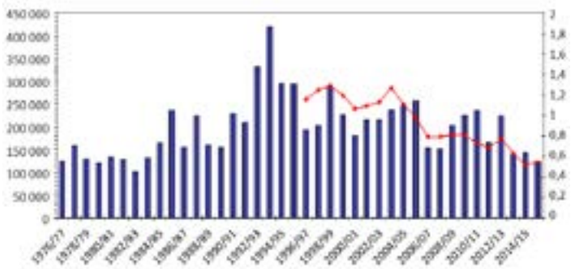
In 1992, the first competitive procurements of basic routine maintenance occurred. Since that year, the competitive procurement of maintenance and operation works has steadily increased and since 1999, 100% of the road network is under competitive bidding. There are basically four contractors that compete for road contracts in Sweden. In beginning of 2017, the division of contractors by km is; Svevia (state owned) 50%, Skanska 5%, NCC 18% and PEAB 22% and others 5%. In the most northerly and southerly parts of Sweden, a couple of smaller contractors have managed to enter the market, having been awarded four areas all in all.

3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

Winter Indexes

During recent years an experimental work has begun calculating a number of winter indices starting from weather situations. Mean values are calculated for each month and for each county. Representative RWIS stations and MESAN scaled weather data are chosen for each contract and values for STA region are given.

The weather index describes the number of occasions with slipperiness, snow and snowdrift, respectively.



SALT CONSUMPION AND SALT INDEX ON NATIONAL ROADS

The salt index describes the actual salt consumption (kg/km) compared to the recommended use of salt (kg/km) for each type of weather situation. A value > 1 means more salt than recommended, and a value < 1 means less salt than recommended.

Training and education

All foremen, who make the decisions about winter maintenance actions, must show that they have a certain competence by passing the national examination SIK (Scandinavian infrastructure competence).

Weather Information provision

RWIS Field stations

Sweden has nearly 800 RWIS field stations located all over the country. The stations are equipped with sensors for measuring air and road surface temperature, humidity, amount and type of precipitation, and wind. Dew point temperature is also calculated and delivered for every station. Most of the stations are also equipped with cameras.

Meteorological information

During the winter season (1st October – 30th April) a contracted weather information service delivers continuous radar and satellite information to the RWIS. Every half-hour, images from the Nordic radar network in different scales are distributed to the RWIS systems central computer.

From the geostationary Meteosat satellite and the orbiting satellite NOAA weather coded images are sent at least every hour to the RWIS system.

Weather maps, with comments, are updated every third hour during the season. All day and night special cloudiness forecasts are produced for a combined statistical and energy model that every hour predicts the road surface temperature for the next six hours.

Internet

The information from the field stations and from SMHI are collected and compiled at an information centre at the headquarters of STA and can then be obtained via the Internet. (See example from www.trafikverket.se)

Measurements of Efficiency

Internal

Both the STA and the municipalities follow up the consumption of salt and abrasives.

External

The road user's satisfaction with winter maintenance is surveyed by the STA every year. The road users are divided into two categories: private and professional drivers.

Road condition

In the most southern region of Sweden the biggest roads have ice and snow condition about 5% of the wintertime (4 months) and the smallest roads 40%. Up in the northern region the corresponding figures are 20% and 70-80% when the winter is 7 month long.

Environmental impact

The main part of the de-icing salt used on the roads will leave the road as run-off or be deposited within some tens of meters but still some amount may be transported further away from the road. The deposition pattern depends on: amount of salt used, intensity, type and speed of traffic, type and amount of precipitation, direction and speed of wind.

The sodium ion participates in ion exchange reactions and is to some extent retarded in soil and groundwater, whereas the chloride ion is conservative and highly soluble. Since the chloride ion is not subjected to retardation or degradation it is a good tracer. If chloride from de-icing salt can be found in a well or in surface water, there is a substantial risk that other pollutants may also be present. Increased chloride concentrations have been observed in both municipal water supplies and in private wells close to roads. Furthermore, the chloride concentration has been observed to increase in lakes in Sweden with concentration peaks during spring. The roadside exposure to de-icing salt may

change the species composition of vegetation and also influence the growth conditions and aesthetically appearance of trees.

Other pollutants from the road and traffic related especially to winter-traffic are metals from corrosion of vehicles, wear of road surfaces and tyres. The fear about wear-particles has increased the last decade.

3.4 TRAFFIC SAFETY AND INFORMATION

Information to road users

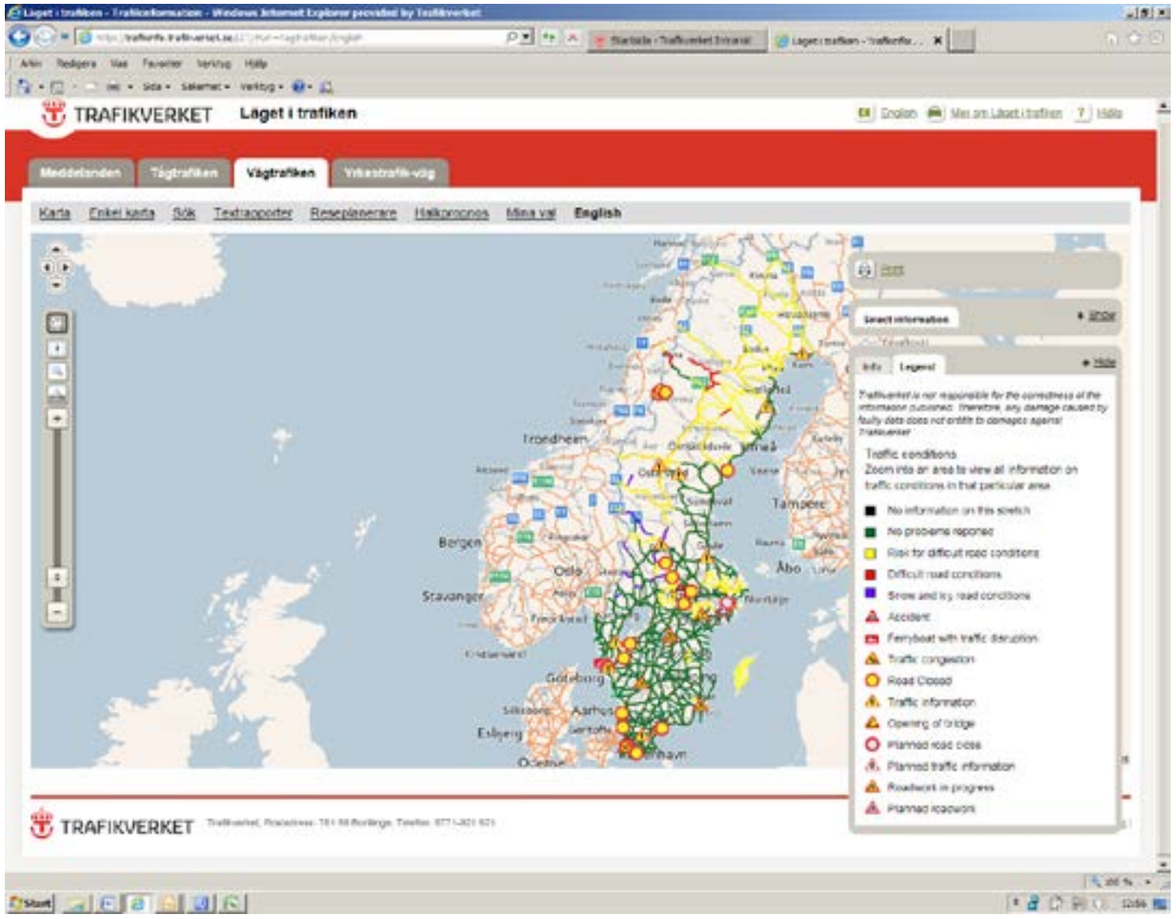
All operation centres have to report at least 3 times a day to the TC (Traffic Centre) and also every time there is a change in road condition (e.g., after a turnout). The information is then distributed from the TC in different ways:

- Radio: Local radio stations get information from the TC
- Newspapers
- Internet: A map showing the present road conditions can be found at the home page of STA (see example from www.trafikverket.se)
- RDS-TMC for real time road condition data for in-car navigators etc.
- Road users can also use web based applications to get information.

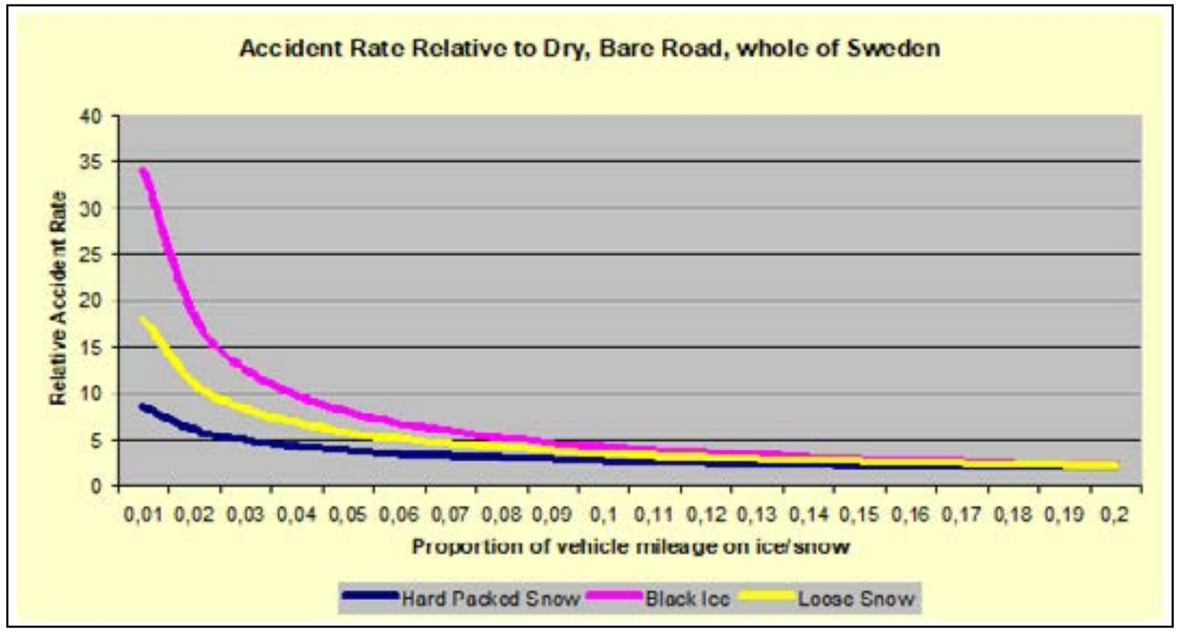
In some places there are traffic signs showing road surface temperature and air temperature.

Traffic safety

Speed and speed adaptation play important roles in



EXAMPLE FROM WWW.TRAFIKVERKET.SE ON ACTUAL ROAD CONDITION



ACCIDENT RATE VERSUS A DRY, BARE SURFACE FOR VARIOUS PROPORTION OF VEHICLE MILEAGE ON ICE/SNOW DURING ONE WINTER

terms of the accidents that will occur with a particular road condition or friction. To stop a private car in more or less the same distance as on a bare road, the car needs to be travelling at half the speed on roads covered with ice or snow. The adaptation of Swedish drivers to ice and snow conditions is, however, significantly less. With a combination of poor road condition and poor visibility (falling snow) speed reductions are about 25%, but when only ice or snow, speed reduction is often between 10% and 20%.

People driving under various road conditions where friction is varied for the various road conditions have shown that it is the appearance of the road and not the road grip which determines the speed that is maintained. This has been observed both in a simulator and on the road. Driving simulator tests have been conducted to determine how best to inform drivers and get the best speed adaption to the friction. Recommended speed display leads to lowest speed and largest headways.

The risk of accidents is estimated as the number of accidents reported by the police per million vehicle kilometres and is known as the accident rate. Accident rates can be calculated either as an absolute value or as a risk relative to a dry bare road in winter. In general, an icy or snowy road condition has about 3-30 times higher accident rate for vehicular traffic than for a dry bare surface. The black ice road condition is the most dangerous. Accident rate can also be calculated as a function of the frequency of occurrence of a given road condition during the winter season.

Accident rates for various icy and snowy road conditions have an exponential relationship with the proportion of total vehicle mileage during the winter season carried out on the current road condition (see figure on previous page).

To study the effect of winter road condition frequency more closely, the winter period is divided into short pre-winter and post-winter periods, with a long mid-winter in between. The accident rate during pre-winter is not higher than during post-winter. This indicates that it is not the first skid phenomenon during a winter period that causes many accidents, but unusual with an icy or snowy road condition that surprise drivers.

Vehicle Equipment

Since 1999 passenger cars, light trucks and buses with a total weight up to 3.5 tonnes shall have winter tyres or equal equipment during the period December 1 – March 31 when winter road conditions (slippery) appear. It is allowed to use studded tyres October 1 – April 30.

A follow-up study showed that this requirement led to an 11% – 14% drop in accidents involving seriously injured and fatalities in icy and snowy road conditions. The interval depends on whether it is assumed that the requirement also has an effect on bare surfaces. Over all road conditions during the whole winter period, the reduction was 8%. These reductions are not statistically significant at the 5% risk level.

ABS (anti-lock braking system) and ESC (Electronic Stability Control) systems proportion the acceleration and/or the braking force in such a way that the tyre is not blocked, and the tangential grip is always used completely to its limit. The accident reduction in Sweden of ESC is for serious and fatal loss-of-control type crashes on roads covered with ice or snow the effectiveness was 49.2 ± 30.2%. It was estimated that for Sweden, with a total of 500 vehicle related deaths annually, that 80–100 fatalities could be saved annually if all cars had ESC.

Pedestrians

The risk of injury is higher to pedestrians than to car drivers when slippery road conditions. When ice/snow is on footways the injury risk is about 8 times higher than when the foot way has bare conditions.

Road furniture

In Sweden it has been quite common with roads with a width of 13 m. When they were built it was with 2 lanes 3.5 m in width and broad shoulders. Those roads had a quite high accident risk and some of them were changed to 2 lanes 5 m in width. But much better results come from the new standard with a guardrail on the road. Often it is 1 lane in one direction and 2 in the other (non-meeting roads with cables). The number of lanes in one direction changes at intersections. This standard resulted in a significant decrease in severe accidents. The fatalities have been reduced to 9 instead of estimated 60 with no cables and severe injuries have had a 50% decrease.

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

The Winter Model

The project "Winter Model" started at the beginning of the 2000s. The idea was to try and predict the consequences of different winter maintenance strategies and to calculate the associated socio-economic costs. It is now possible to calculate and validate the impact that different winter maintenance measures have on road users, road authorities and local communities. This model will continue to be developed in the coming year. For instance, the accident model will get updated.

At the heart of the winter model is the Road Condition Model. This model provides the foundation for the other sub-models, because it is here road conditions are calculated. The models input values are weather conditions from a RWIS-station, together with annual average daily traffic (AADT) and information about the climate zone and road standard class.

Sweep-salting

In order to be able to cycle safely, a high winter maintenance service level is required. Although the method has certain drawbacks and difficulties, using salt for skid control on bicycle paths could be one solution. In recent years, a method using a front-mounted power brush for snow clearance and salt for de-icing – commonly called "sweep-salting" – has become more and more popular for maintaining bicycle paths in Swedish municipalities. One challenge is to develop and optimise equipment, methods and maintenance strategies associated with "sweep-salting". This is necessary when striving to achieve a maintenance service level that is as high as possible under different conditions and circumstances

RSI

Road Status Information (RSI) is a new type of service where a number of different sources of information work together to make current road maintenance practices more efficient. In order to assess future road surface conditions and to plan relevant maintenance measures, the Swedish Transport Administration and its subcontractors now use forecasts, satellite information and radar pictures from weather prediction services in conjunction with RWIS.

Ongoing RSI projects contain a number of new information sources that can help to improve forecast accuracy and the follow-up of any measures taken. RSI can be described as an advanced decision making and follow-up system that can be used to improve road climate conditions and save resources.

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From the homepages below most of the reports can be downloaded.

www.vti.se Swedish Road and Transport Research Institute (VTI)

www.trafikverket.se Swedish Transport Administration (STA and in Swedish VV)

www.smhi.se Swedish Meteorological and Hydrological Institute (SMHI)

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

Switzerland is a small (41,285 km^2), landlocked country in the heart of Europe. Roughly two-thirds of its surface is mountainous. The Midlands between the Alps and the Jura mountain chain is densely populated.

Switzerland is a federal state with 26 cantons. The capital is Berne. Zurich and Geneva are international financial centers. Geneva accommodates the headquarters of several UN organizations as well as other international organizations. Basel is the seat of major pharmaceutical multinationals.

Four cultures or linguistic regions coexist in Switzerland: German: 64% of the population, French: 20%, Italian: 7%, and Romansch (in some alpine valleys): < 1%.

The economy is based on services (71%), industry (25%) and agriculture (4%). Export commodities are: machinery, chemicals, metals, watches, agricultural products.

NINE PERCENT (9%) OF THE POPULATION SPEAKS OTHER LANGUAGES.

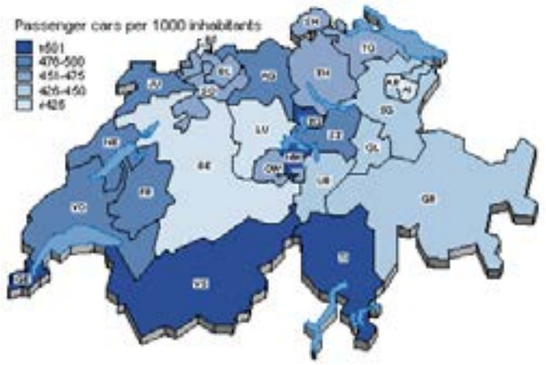
1.2 ROAD NETWORK AND TRAFFIC

Roads	National roads	1,700 km
	Cantonal roads	18,000 km
	Communal roads	51,000 km
Vehicles	Utility vehicles	292,329
	Passenger cars	4,147,500

The Confederation owns the national roads and has full authority over the latter. The network of Swiss national roads, comprising a total length of 1,907 km, was defined as a whole in 1960. Close to 90% built, it will theoretically be completed by 2020. Construction has now made way for adaptation and review of the network.

The cantons and communes respectively own the cantonal and communal roads.

The average Swiss travels 11,000 km a year in private cars and 2,100 km by train. The average daily traffic on motorways reaches 100,000 vehicles on certain stretches (3+3 lanes). Road transport accounts for 85% of the total freight tonnage. The economic importance of roads is therefore very high. The federal, cantonal and communal road authorities are responsible for keeping the roads serviceable at all times.



Winter maintenance is in operation between October and April and accounts for 20-25% of the yearly operational cost.

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

About a hundred of Switzerland's mountain peaks are close to or higher than 4,000 meters and there are more than 3,000 square kilometers of glaciers. Forests occupy about a quarter of the country.

The climate varies according to altitude. Four characteristic climate regions can be distinguished:

Jura

The Jura is a mountain chain in the northwestern part of the country. The highest peak reaches 1,300 meters.

High precipitation, accompanied by frequent strong winds, prevails. The winter climate is harsh. Precipitation averages between 120 and 180 cm over 140 to 160 precipitation-days a year. Strong winds reach peak speeds up to 140 km/h and 210 km/h at the mountaintops. In winter, blowing snow is frequent.

Midlands

More than two-thirds of the population lives in the region between the Jura and the Alps. All the major cities lie in this region. The altitude varies from 300 to 700 meters.

A well-balanced distribution of precipitation prevails. The quantity of snow varies from winter to winter and fog is a frequent phenomenon.

Precipitation averages between 90 and 140 cm over 120 to 140 precipitation-days a year. Strong winds reach peak speeds of up to 170 km/h.

Alps

The Alps and Pre-Alps cover almost two-thirds of Switzerland's surface. The highest peak stands at 4,500

m. The Alps and Pre-Alps are generally rich in precipitation. Precipitation averages between 140 and 200 cm for 140 to 160 precipitation-days a year. Strong winds with peak speeds of up to 270 km/h are possible in the valleys. Foehn winds (hot and dry) are frequent in north-south oriented valleys.

Southern Alps

Ticino, the sunny part of Switzerland, lies south of the Alps, where palm trees grow. The altitude descends to 200 meters.

High yearly precipitation of up to 220 cm prevails as a result of the rain accumulation on the southern face of the Alps in the spring and autumn. Wind speeds go up to 120 km/h.

2.2 STATISTICS ON TEMPERATURES

The table shows the winter characteristics of the various climatic regions.

2.2 WINTER INDICES USED IN THE COUNTRY

A winter index was developed to show the correlation between winter maintenance costs and various meteorological parameters. It has served as a basis for determining compensation for winter maintenance since 2008.

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Legislation differs for national, cantonal and communal roads. A legal obligation to ensure winter maintenance exists for the national roads.

The official codes of practice for roads comprise 18 documents on winter maintenance.

SN 640 750b	Bases;
SN 640 751	Avalanche Protection;
SN 640 752b	Manpower Training and Requirements;
SN 640 754a	Weather Information, Record of Road Conditions;
SN 640 756a	Priority, Winter Service Levels, Route Planning and Register and Response Plan;
SN 640 757a	Intervention Equipment;
SN 640 760b	Snow Characteristics;
SN 640 761a	Snow Removal;
SN 640 763	Engines for Snow Removal;
SN 640 764b	Attachment for Snowplows;
SN 640 765a	Snowplow characteristics;
SN 640 772b	Ice Control;
SN 640 774a	Requirements for Spreaders;
SN 640 775a	Snow Fences;
SN 640 776b	Structures for Snow Stabilization;
SN 640 778a	Signage, Facilities.

Climate	Air temp		Precipitation					
	Days where T< 0° C	Frost days	Days with rain	Rain in cm/ year	Days with snow fall	Days with snow cover	Max. snow cm/day	Amount of snow cm/ year
Jura	121	30	157	140.6	64	123	55	317
Midl	96	22	126	104.2	30	51	22	53
Alps	140	42	138	148.7	59	128	50-90	433
SoA	45	4	107	184.8	14	19	63	43

Road classes

For snow removal and ice control, the following classes have been defined:

- Motorways, highways;
- Main arteries, steep roads;
- Roads used by public transportation;
- Roads leading to railway stations, hospitals, etc.;
- Public transportation stations;
- Major pedestrian and bicycle paths, stairs.

Service levels

Level A:	bare roads, complete snow removal and ice control;
Level B:	prevention of slipperiness, bare roads in the medium term;
Level C:	roads practicable without the use of de-icers, white roads;
Level D:	no winter maintenance.

Priority levels

Level 1: First snow removal pass completed 3 hrs after mobilization (2 hrs on motorways). First spreading pass completed 2 hrs after mobilization.

Level 2: First snow removal pass completed 4 hrs after mobilization. First spreading pass completed 3 hrs after mobilization.

Level 3: First snow removal pass completed 5 hrs after mobilization. First spreading pass completed 4 hrs after mobilization.

All road authorities are obliged to have route maps covering the entire road network where road classes, service levels and priority levels are indicated.

Regulations for manpower

Maximum driving time is stipulated in a national ordinance. It must not exceed 9 hrs (10 hrs allowed twice a week). Weekly working time is 46 hrs. Maximum weekly overtime is 5 hrs (10 hrs in special cases).

Exceptions are, however, allowed for maintenance services. Conditions vary slightly from canton to canton.

Regulations for equipment and material

The regulations for equipment describe the types, test methods and operational areas of vehicles, snowplows, snow blowers, and spreaders. The main objectives are:

- Highest possible speed for plows/spreaders;
- Complete snow removal through mechanical means (plows, rotary brooms);
- Minimal use of thawing agents.

The codes of practice describe the types and operational areas of de-icing agents (NaCl, CaCl2, MgCl2, Urea, salt solutions, methanol, and glycol) and abrasives.

The dosages prescribed are:

Spreading	Temperatures °C	
	0°C to -8°C	-8°C to -20°C
	g/m2	g/m2
Dry salt Wet salt Brine [in ASI]	7 – 15 7 – 15 5 - 10	10 - 20 10 - 20 5 - 10
Abrasives	⩽ 200	⩽ 200
Mixing ratio	only NaCl	2/3 NaCl 1/3 CaCl2

Certain surface conditions may require a higher salt dosage.

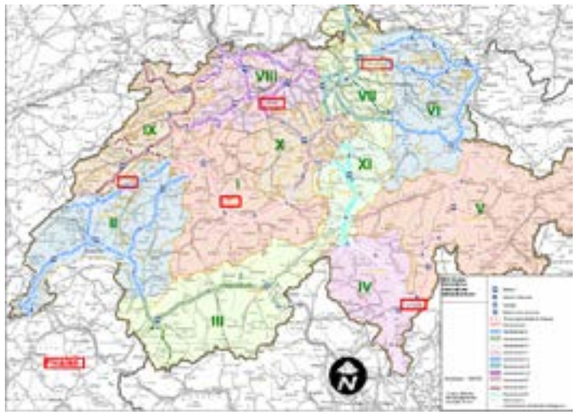
Progress is being made in the use of the wet salt technique (salt and brine mixed on the spinner). In 2005 this technique was used in 90% of all motorway maintenance centers.

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

The Confederation is responsible for winter maintenance on the national roads. It awards service contracts to 11 territorial units across Switzerland who perform the winter maintenance.

Winter maintenance on cantonal roads is performed by the cantons, and winter maintenance on communal roads is performed by the communes.

In general, the maintenance centers are responsible for winter maintenance. However private companies are frequently given contracts to do part or, in some cases, all of the winter maintenance. The contracts are established between the cantonal or communal road authorities and the contractor.



Types of contract:

A: The contractor is in charge of a stretch of road for snow plowing and ice control. He works with his own equipment, except plows and spreaders, which are provided by the maintenance center. The call for intervention is in most cases given by the maintenance center.

B: The contractor provides vehicles and drivers, who work together with the maintenance center's crews.

C: The contractor provides vehicles for the winter season.

Payments are based on the number of work hours with a flat rate for providing the vehicles.

National roads

Equipment: The national roads have 45 maintenance centers. The average length of highways serviced by each center is defined by the obligation to do the first round of winter maintenance within 2 hours.

The equipment includes: 2-3 trucks per direction, equipped with plows, 3.5-6.0 m width, detachable spreaders, 4-6 m3 for salt and 2 m3 brine. One person per truck. On mountainous stretches and on stretches where the snow cannot be pushed to the side, snow blowers are required to load the snow on trucks.

Salt is always stored under shelter, either in barns (up to 4,000 tonnes) or in silos (200 tonnes per silo). The advantage of the silos is the short time needed for loading (2-3 minutes), which can be done by the driver alone. With an appropriate arrangement of the silos, 2-3 spreaders can be loaded at the same time.

Automatic de-icer spraying facilities are in operation on specific stretches with a particular microclimate or which are particularly exposed. Two facilities are on high bridges, one facility (6 km length) on a segment with heavy traffic (80,000 vehicles per day) and a particular microclimate.

Road heating is not used, but for one exception. On a particularly exposed bridge, a solar energy pilot application is in operation since 1995. A heat exchanger tube system embedded in the asphalt layer of a bridge, covering an area of 1,300 m2, collects heat during the summer and utilizes it during frost periods in the winter to heat the bridge's surface, thus preventing the formation of ice. The liquid is stored in an underground heat store.

Manpower

The maintenance center staff usually consists of:

- One road master responsible for winter maintenance;
- One administrator, responsible for accounting and administration;
- Two to three group leaders;
- Crews, drivers and other professions;
- Two to three mechanics;
- One to four electricians, depending on the number of electromechanical facilities along the highway.

Group leaders are responsible for operational tasks. They decide on interventions, based on the RWIS. Each maintenance center has a standby organization during the whole year. Each employee is obligated to provide temporary standby availability.

The work schedule is set by the head of maintenance operations in each canton. As a rule, the work week is of 42 hrs. Overtime during winter is generally compensated in summer.

Shift working is becoming more common in the maintenance centers as the intensity of the workload increases. Maintenance work in tunnels is mainly done at night and more and more this also applies to other work likely to hinder the flow of traffic.

There are strict safety rules for every type of maintenance work (clothing, tool-handling, equipment, behavior on the road etc.). Every center has a designated safety supervisor.

Training and education

The head of the maintenance center is responsible for crew training.

- Training includes:
- Winter maintenance tasks;
- General organization;
- Vehicles and heavy equipment;
- Response organization;
- Personnel and standby organization;
- Supply of information;
- Instruction on tools;
- Preparation of group leaders;
- Instruction on route planning, service levels and priority levels;
- Application of salt according to RWIS forecasts and residual salt;
- Plowing in teams;
- What should be done in the event of an accident, „risk management";
- Reporting.

At the beginning of winter, courses are given to road operators on basic meteorology, forecasting technology and work on the RWIS and the weather radar.

Other courses cover the handling of ice detection systems.

Methods, equipment and materials for special problems

Special problems are caused by snow drifts, avalanches and porous asphalt. To reduce the amount of snow blown on the road, snow fences are put up where the phenomenon regularly occurs.

In some winters, avalanches cause severe problems for road authorities. In all mountain regions, a special avalanche task force has been organized. Their duty is to observe the characteristics and the amount of snow and to issue warnings, and in some cases to close the road. A special avalanche bulletin and warnings are issued daily by MeteoSwiss and the Swiss Avalanche Research Institute. Automatic warning devices have been installed in certain locations.

Meteorological information

MeteoSwiss provides information for winter maintenance on several levels:

General road weather forecasts, available to the general public on the Internet and the radio. Free of charge.

- A 24-hr road weather forecast specifically designed for maintenance centers. These forecasts are made separately for more than 20 areas with different local climates.
- The information is distributed via telephone lines and the computer network and goes directly to the maintenance center's RWIS computer. The contract is established between MeteoSwiss and the maintenance center. Accuracy is between 86% and 89%.
- Weather forecast warnings are issued for special events or situations, whether general or local, that have not been announced in the general weather forecast. They are delivered directly to the maintenance center's RWIS computer and trigger a warning signal.
- The MeteoSwiss road weather forecasts rely on a network of automatic weather stations (ANETZ) and several forecast models. Verification is usually done with selected road sensors.

SWITZERLAND

RWIS

All maintenance centers for the national roads have a RWIS. The system combines measurements and warnings from road sensors, road weather stations and local weather forecasts. Road sensors and road weather stations generally provide the following parameters: air temperature 2 m aboveground, surface temperature, humidity, dew point, freezing temperature, precipitation, wind: direction and intensity, road conditions: dry or wet, residual salt.

The RWIS local weather forecast is issued every day at 3:00 p.m. and covers 24 hrs. It provides: air temperature 2 m and 5 cm aboveground, humidity and dew point, precipitation: type and quantity, snowfall threshold, wind: direction and intensity, cloud cover, road surface conditions. The forecast is updated if a change occurs in the 24 hrs.

Ice detection system

The national road network is equipped with an ice detection system. In total, about 400 road sensors have been installed and measure the surface temperature and the freezing point by electrically cooling down the sensor surface. The average distance between road sensors is approximately 6 km.

The most widespread system is the Boschung system. In a few cases, the Vaisala and the Micks systems have been installed. The road sensors are generally combined with roadside measuring stations. The location of the sensors was determined by experience or through thermal mapping. Generally, the most dangerous spots were chosen. Additional locations are on bridges, in particularly exposed and shady areas.

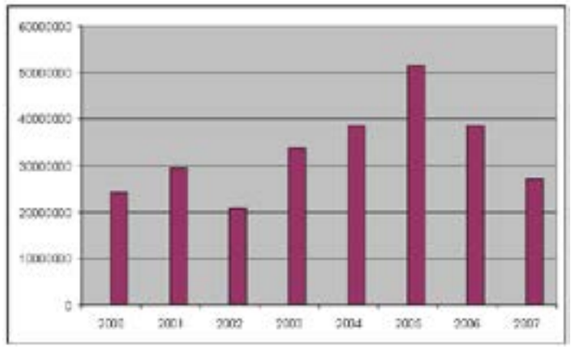
3.3 ASSESSMENT OF WINTER MAINTENANCE MEASURES

Operating costs on national motorways

Winter maintenance costs can vary between 15% and 25% of total annual operating costs. The following diagram shows the winter maintenance costs in 1,000 CHF per vkm.

(vkm: virtual kilometers, where additional traffic surfaces such as service areas, ramps, braking lanes, etc. are calculated as additional kilometers)

Salt consumption on national motorways



ANNUAL WINTER MAINTENANCE COSTS

Salt consumption is directly related to the harshness of the winter. Several measures have been introduced in the past years to minimize the use of deicers systems. The annual consumption is shown in tons/km.

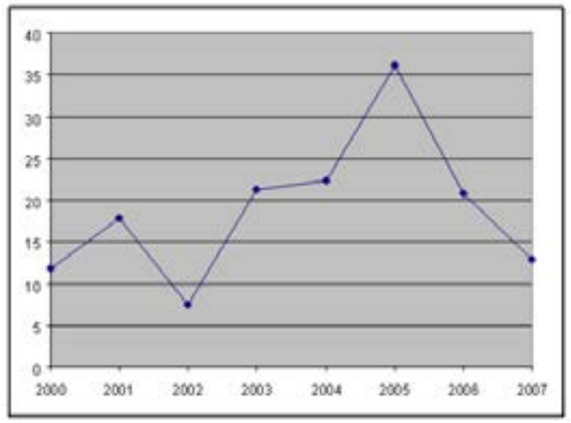
MEASUREMENTS OF EFFICIENCY

Internal

All the maintenance centers for national roads and some for communal roads have a cost accounting system. Therefore the total cost of winter maintenance, as well as the personnel, vehicles/engines, material etc. cost factors are exactly known. Based on this cost accounting, efficiency assessments are made after every winter.

A knowledge exchange project covering all maintenance activities is currently underway. The project objectives are:

- Increasing efficiency;
- Institutionalizing learning programs;
- Reducing costs.



HISTORY – ANNUAL CONSUMPTION (T/KM)

External

The external efficiency can basically be judged by the number of road closures and traffic accidents caused by poorly maintained roads. These occurrences are, however, only summary.

A more detailed method, which will compare activities with the given standards, is actually in the preparatory stage. It will be based on a general road maintenance quality assurance.

Measures aimed at reducing the salt consumption

Besides the approved methods like the wet salt technique, dosage prescriptions according to surface conditions and annual staff education, new procedures and devices are systematically tested for their efficiency.

A test conducted over two winters with an automatic salt dosage system based on „ThermoMat" infrared thermometers has proven that the salt consumption on a motorway can be reduced by 20% to 30% without any reduction of the road safety, providing both environmental and economic benefits in ice control.

3.4 TRAFFIC SAFETY AND INFORMATION

Safety measures

In a large national project called Via Sicura aiming to reduce the number of victims on the road, a number of measures indirectly related to winter maintenance have been defined.

Weather-related information for road users

This kind of information is mainly available by radio. The road administration does not provide any on-site information on road weather or road surface conditions.

However, fixed and variable road signs provide information on closed roads and recommended detours.

SWITZERLAND

International exchange of road information

International information exchanges regard road closures and difficult driving situations. This exchange is ensured by police headquarters.

Traffic management on national roads

There are supraregional offices for traffic management. These traffic guidance centers are responsible for such operations as the collection of data on traffic flow and density, active traffic guidance, the coordination of road maintenance, and information on traffic, the weather, and road conditions.

4 ONGOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGY

Criteria for the implementation of automatic de-icer spraying facilities

This study will provide project evaluation criteria for the use of automatic de-icer spraying facilities in respect of microclimate, traffic, safety and cost/benefit.

4.2 NEW MANAGEMENT APPROACHES

Winter index

The winter index is an empiric formula based on winter maintenance costs and meteorological data. It can be applied to evaluate the theoretical operating costs resulting from the meteorological data from the past winter and thus provide an indication of the efficiency of winter maintenance.

Effectiveness of road winter service

The research will show the traffic flow before and after winter maintenance and thus allow cost/benefit considerations on the propriety and the promptness of winter maintenance operations, including traffic safety, economy and the environmental impact.

Use of modern communication technology in road maintenance to optimize traffic safety

The study will provide the technical and financial criteria for implementing such communications as satellite-based positioning, online data transfers between the base and vehicles, remote-controlled salt dosage, etc.

4.3 TRANS-NATIONAL COOPERATION

In the area of winter road maintenance, Switzerland collaborates with the following organizations:

PIARC World Road Association, Technical Committee B5 „Winter Maintenance";

COST European Cooperation in Science and Technology, Project 353 „Winter Service Strategies for Increased European Road Safety";

SIRWEC Standing International Road Weather Commission, Executive Committee;

CEN European Committee for Standardization, TC 337 „Winter Maintenance and Road Service Area Maintenance";

D-A-CH Annual seminars organized by the road research associations of Germany, Austria and Switzerland;

F-CH Regular seminars on technical and organizational issues organized by the road research associations of France and Switzerland.

In the past Switzerland has hosted the following international conferences on winter issues:

PIARC VI International Winter Road Congress, Davos, 1982;

SIRWEC 10th International Road Weather Conference, Davos, 2000.

5 REFERENCES

Swiss Federal Roads Authority
www.astra.admin.ch
Other references
www.swissroads.ch
www.vss.ch

UNITED KINGDOM

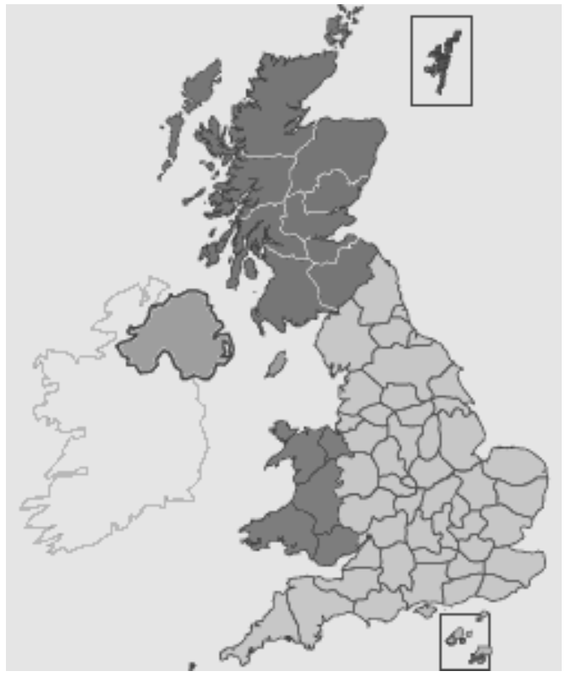
1. DEMOGRAPHICS AND ROADS

1.1. INFORMATION ABOUT THE COUNTRY

The United Kingdom is made up of four countries, namely England, Northern Ireland, Scotland and Wales. The total area of the United Kingdom is 243,800 km², split up as follows:

England – 130,400 km²
Northern Ireland – 13,800 km²
Scotland – 78,800 km²
Wales – 20,800 km²

The physical geography of the UK varies greatly. It includes the chalk cliffs of the south coast, the rolling hills and fields of southeast England, the granite cliffs of the southwest peninsula, the mountains of Wales, the lakes and mountains of northern England, the Scottish lowlands, highlands and islands, and the fields, lakes and mountains of Northern Ireland. The 61 million population in the UK is rather unequally distributed among the four countries: 51 million in England, 2 million in Northern Ireland, 5 million in Scotland, and 3 million in Wales.



HIGHWAYS ENGLAND'S STRATEGIC ROAD NETWORK (SOURCE: HIGHWAYS ENGLAND)

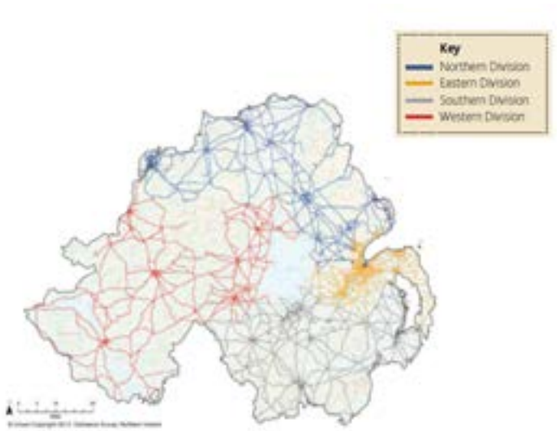
1.2. ROAD NETWORK AND TRAFFIC

The road network in the United Kingdom comprises 14,568 km of motorway and trunk roads and 405,473 km local roads.i Road traffic on this network is 488.9 billion vehicle kilometres per year (excluding Northern Ireland).ii Each country within the United Kingdom uses a different approach to network management.

England – The English network consists 7,300 km of motorway and trunk roads and 294,000 km of local roads. The Department of Transport delivers transport through a number of executive agencies and government owned companies with responsibility for the various modes of transport. Previously known as the Highways Agency, Highways England was established in 2015 as a government owned company with responsibility for managing most of the motorway and trunk road network. Local authorities, usually County Councils, have the responsibility for managing local roads. Transport for London is responsible for all forms of public transport in London, including all roads.

Northern Ireland Road Network - There are 25,591 kilometres of public road in Northern Ireland. Unclassified roads account for the largest proportion of all roads (61%) followed by C roads (18%), B roads (11%), A roads (9%) and Motorways (<1%)

The Department for Infrastructure, Roads Winter Service Policy provides for precautionary salting on approximately 7200kms of this network. This service is



MAIN SALTING ROUTES IN NORTHERN IRELAND
(SOURCE: THE DEPARTMENT FOR INFRASTRUCTURE, ROADS)

SCOTTISH TRUNK ROAD NETWORK
(SOURCE: TRANSPORT SCOTLAND)

carried out at the most effective times to try and prevent ice from forming therefore helping to facilitate the free and safe movement of traffic. This salted network equates to some 28% of the total Northern Ireland road network

The Department for Infrastructure, Roads maintains a fleet of approximately 130 winter service spreaders and 12 Snow blowers to manage this network.

The Northern Ireland Salting Network is fairly extensive and the scale of the map only allows for the main routes to be shown.

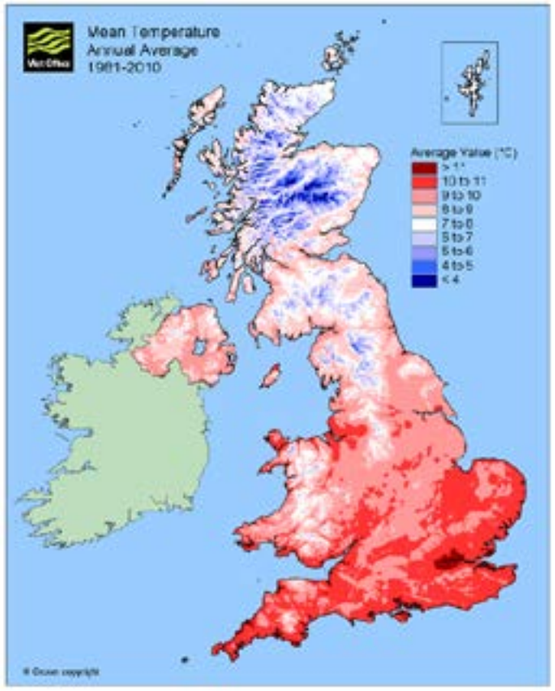
Scotland – The Scottish road network comprises

3,400 km of trunk roads and 56,000 km of local roads. Transport Scotland is responsible for managing and maintaining Scotland's motorways and trunk roads. Winter service is delivered by five operating company units and five DBFO company contracts. The 32 local authorities have the responsibility for managing local roads.

Wales – The Welsh road network comprises 1710 km of trunk roads and 32,933 km of local roads. Welsh Government has the responsibility for managing major roads, which is comprised of trunk roads, including motorways. Local unitary authorities have statutory powers and obligations for all public highways, which are not trunk roads or motorways.

In England and Scotland management and maintenance of trunk and motorways are procured on the basis of competitively tendered contracts. Service providers are appointed to operate specific geographical areas for a period of five to ten years, and up to 30 years on DBFO contracts. In Wales this service is predominantly managed and delivered through two local authority partnership based Trunk Road Agents. The Department for Infrastructure, Roads is responsible for all roads in Northern Ireland with the exception of motorways which are maintained through a Public, Private Partnership contract. The length of motorway in Northern Ireland is 115 km (exc slips).

WELSH STRATEGIC HIGHWAY NETWORK
(SOURCE: WELSH GOVERNMENT)



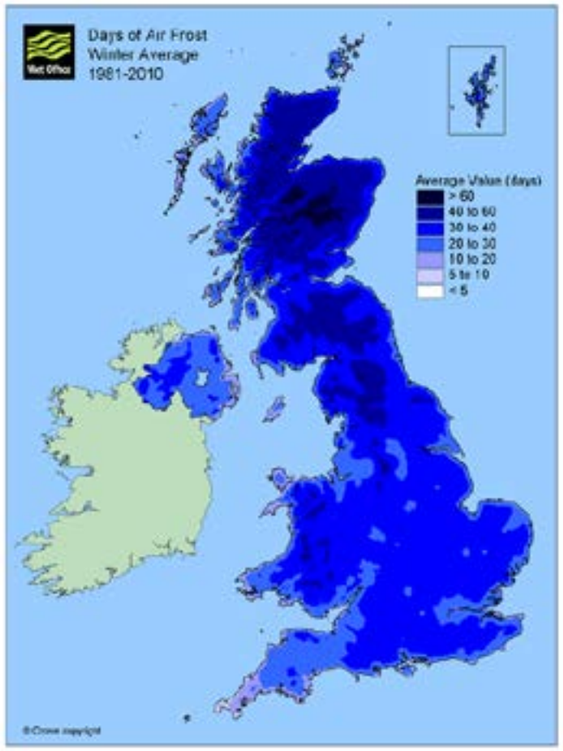
2. CLIMATE

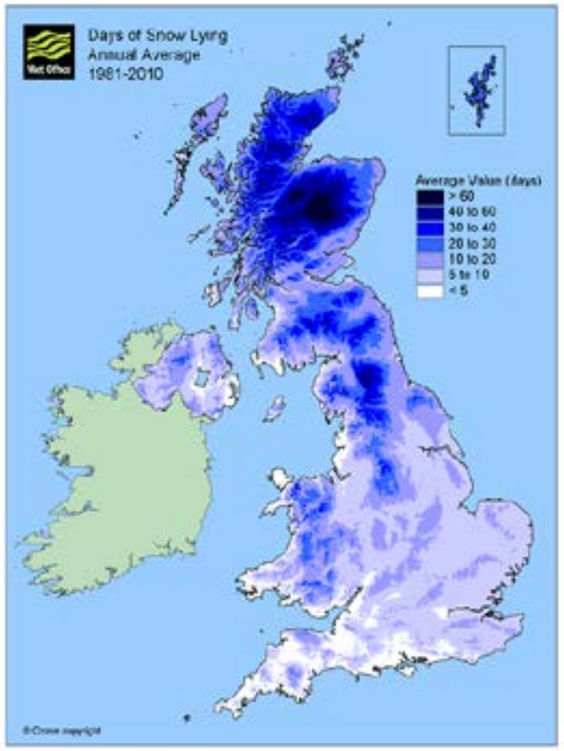
2.1. OVERVIEW OF CLIMATIC AREAS

The climate of the United Kingdom is classified as temperate, with warm summers, cool winters and plentiful precipitation throughout the year. The principle factors of influence on the climate include the UK's northerly latitude (which ranges from 50° to 60° N), its close proximity to the Atlantic Ocean and, especially, the warming of the waters around the British Isles by the North Atlantic Drift together with the effects of the Gulf Stream. The weather can be notoriously changeable from one day to the next but temperature variations throughout the year are relatively small.

2.2. Statistics on temperature, icing and precipitation days

The UK is at the boundary of convergence between the warm tropical air to the south and the cold polar





air to the north. In this area, the large temperature variation creates instability and this is a major factor that influences the changeable and often unsettled weather the UK experiences, where many types of weather can be experienced in a single day.

	MaxTemp [deg C]	MinTemp [deg C]	Days of Frost [days]	Rainfall [mm]
England	13.5	5.9	49.1	855
N. Ireland	12.4	5.4	42.8	1136
Scotland	10.7	4.2	67.4	1570
Wales	12.6	5.7	49.3	1460

1981-2010 Averages (Source: Met Office)

Winter in the UK is generally a cool, wet and windy season. Temperatures at night rarely drop below -10 °C and in the day rarely rise above 15 °C. In the period from 2005-2010, snowfall had become more frequent. However, in the last few years heavy rainfall and high winds have presented the UK with the most significant challenges.

Towards the end of the winter season the weather usually stabilises with less wind, precipitation and lower temperatures. This change is particularly pronounced near the coasts mainly due to the fact that the Atlantic Ocean is often at its coldest during this time after being cooled throughout the autumn and the winter.

2.3. WINTER INDEXES USED IN THE COUNTRY

In England, Northern Ireland and Scotland, the Met Office makes use of the Meteorological Office Open Road Index (MOORI). This index reports weather conditions and is typically presented in (i) long term averages of the nights of salting actions, (ii) month-by-month differences from the average, and (iii) whole winter differences from the averages, for each weather station. In addition, graphs are produced to illustrate long-term trends.

Typically in the UK there are three winter maintenance periods for normal operational purposes: (i) High Risk Period (typically December, January and February), when severe conditions might reasonably be expected;

(ii) Low Risk Period (November and March), when severe conditions may occur; and (iii) Marginal Risk Period (mid-September, October and April), when severe conditions are generally not expected.

Local highways/roads authorities throughout the UK make use of similar classifications. These periods have an impact on the winter service delivery requirements in service providers contracts.

3. WINTER ROAD MANAGEMENT

3.1. STANDARDS AND RULES

Highways/roads authorities in the UK have a statutory duty to maintain highways/roads with effective winter service being one element of that responsibility. The statutory basis for winter maintenance differs throughout the countries.

Highways Authorities in England and Wales have a statutory duty to "ensure, so far as is reasonably practicable, that safe passage along a highway is not endangered by snow or ice".iii In addition, the Highways Act 1980 also imposes a duty upon authorities to remove obstructions of the highway resulting from "accumulation of snow or from falling down of banks on the side of the highway, or from any other cause".iv

In Northern Ireland, the Roads (Northern Ireland) Order 1993 requires The Department for Infrastructure, Roads the highway authority to remove snow and take such action, as it considers reasonable to prevent snow or ice interfering with the safe passage of persons and vehicles using the road.

In Scotland roads authoritiesv have a statutory obligation to take "such steps as it considers reasonable to prevent snow and ice endangering the safe passage over public roads."vi

Highways England aims to provide a winter service, which, as far as possible, allows the safe movement of traffic on motorways and all-purpose trunk roads in England, and keeps delays and accidents caused by adverse weather to a minimum. The winter service delivery requirements for the strategic road network in England are set out in the Severe Weather Plan template which forms part of each service provider's contract.

The Welsh Government Trunk Road Maintenance Manual; Part 5: Adverse Weather Service sets out the requirements and the advice of the Welsh Government [–Department for Economy and Infrastructure] for adverse weather and winter service activities on motorways and all-purpose trunk roads which are within the responsibility of the Welsh Government, whereby top priority is given to the motorways and the more important all-purpose trunk roads.

3.2. ORGANISATION AND OPERATION OF WINTER MAINTENANCE

The budget for winter service on roads in the United Kingdom is an estimated £150 million per annum. England and Wales spends approximately £20 million and £5 million on motorways and trunk roads winter service during an average winter respectively. Scotland spends up to £14 million on winter service. In Northern Ireland, the average winter service operation costs between £5 and £7 million.

Both the English and Welsh trunk road maintenance manuals outline roles, responsibilities, operational purpose and techniques, application of salt and alternative de-icers, use of maintenance plant and equipment, liaison and communication.

Roles and Responsibilities – Highways England, The Department for Infrastructure, RoadsNorthern Ireland, Transport Scotland and the Welsh Government [Department for Economy and Infrastructure] are responsible for setting the overall policy on the provision of winter services on the motorway and trunk road network. The service providers and maintenance agents normally undertake the operational management of the service and provide the necessary labour materials and in most cases the plant. In England on the strategic road network Highways England provides the full fleet of dedicated pre-wet spreaders and snow blowers for the service providers to operate and about 75% of the depots to operate out of.

Service providers and highways/roads authorities throughout the UK typically prepare a severe weather/winter service plan updated annually, which describes the policy, objectives, procedures and operational arrangements. This document is often made widely available so that local residents, transport firms and local industries may be informed of the level of service to be expected. In addition, the document details unique local conditions and how a satisfactory level of service will be provided, while at the same time complying

with local, regional or national specific legislation.

Operational Purpose and Techniques – The operational arrangements within the severe weather/winter service plan define the precautionary pre-treatment network, the preparation, the dedicated spreading and snow-clearance plant, strategically sited stocks of de-icing agents, ice/snow prediction and monitoring, action/operational procedures for the treatment of ice and snow, defined procedures for public information/media coverage, and monitoring the effectiveness of action.

Pre-treatment is undertaken on all the major routes of the network and provides the most effective way of ensuring the safety of these routes where the majority of vehicle movements take place. The definitions and criteria applied to determine the precautionary pre-treatment network vary considerably between countries and highways/roads authorities.

The guide used by many is Appendix H of the Well-Maintained Highways Code of Practice which sets out the general national standard. The precautionary pre-treatment network will typically comprise a maintenance category priority order as indicated in the following table.

Maintenance category	Road type	Function
1	Motorways	Major road
2	Primary national trunk	Major road
3	National primary	Major road
4	Primary county	Interurban and through routes
5	Secondary county	

In addition to defining the network on a maintenance category basis, consideration is given to the criteria such as traffic flows, settlement population, emergency premises, adjoining highway authority salting networks with respect to lower road categories and important facilities for cycling and walking.

Treatment route optimisation exercises are carried out to maximise efficiency and ensure coordination with other routes. This exercise improves the targeting of pre-treatment operations and minimises inappropriate treatment on marginal weather forecasts by determining action on a route-by-route basis. The precautionary pre-treatment network is typically denoted on a map. In addition, route cards and maps are produced for each precautionary spreading route and copies retained in the assigned spreading vehicles at all times. The precautionary spreading network is reviewed annually to reflect developments, improvements and changes in traffic patterns.

Highways/roads authorities and service providers define the planned winter service operations by late summer. The issues typically discussed at the winter preparation operations and pre-winter meetings are preparation of winter service plant and equipment, calibration of road weather sensors, plant and equipment, certification of plant operatives, preparation of winter service cover, de-icing agents stocks, contact/stand-by systems and rotas.

In addition to precautionary treatments in Scotland, winter patrols operate on all motorways and selected major routes. Winter patrols are deployed to monitor conditions, provide salt treatments and plough as required.

Winter patrols operate on the busiest roads and those trunk roads that experience the severest winter weather when temperatures are forecast to be low and there is a risk of ice forming. Patrols operate from early morning through to the end of the morning peak period and at other times of the day when severe wintry weather is forecast, at the discretion of the Operating Company winter managers.

Patrol vehicles are fitted with surface temperature sensors which allow winter decision makers to monitor, in real-time, the road temperature at the location of each patrol vehicle. All motorways have a maximum 30 minute response time to winter incidents when the patrols are deployed.

UNITED KINGDOM

The Application of Salt – The management of the salt stock and its replenishment is an essential element of effective winter service. Minimum holdings are specified for each depot, which can be varied over the winter period. The salt stock levels are generally based on historical information and are sufficient to cope with an average winter and are topped up should extreme weather conditions occur.

The use of salt barns, which is becoming more widespread across the UK, ensures that salt is maintained with low moisture content, preventing leaching and allowing easier handling of the salt.

The quality, chemical composition and uniformity of salt are important to ensure control of the rate of spread. Rock salt is used by most organisations in preference to vacuum and marine salt, mainly on the basis of cost. Generally, a fine grading of rock salt is used for precautionary salting due to reduced vehicle damage and a more uniform spread on the carriageway together with minimising overspread and contamination of adjacent vegetation.

Type and grade		BS410 test sieve	% passing
Rock salt	Coarse	10 mm	100
		6.3 mm	75-95
		2.36 mm	30-70
		300 µm	0-20
	Fine	6.3 mm	100
		2.36 mm	30-80
		300µm	0-20
Vacuum salt and marine salt	Coarse	10 mm	100
		1.18 mm	0-80
		150 µm	0-10
	Fine	1.18 mm	100
		150 µm	0-30

Grading of Salt (BS3247)

Highways England's fleet of winter spread pre-wetted salt. Tanks fitted to the sides of the bodies on the new vehicles carry brine, which during treatments, is mixed with dry salt in measured proportions, to create the optimum blend (typically a 70:30 ratio, dry salt to brine). This pre-wetted salt is spread onto the surface of the road in a similar manner as if carrying out purely dry treatments. In Scotland all front-line vehicles use pre-wetted salt and pre-treatment routes are designed to allow a maximum 40g salt treatment to be delivered in a single pass.

During season 2016-17 transport Scotland introduced full brine precautionary treatments. This followed trials during the previous winter period in conjunction with TRL to assess the effectiveness and suitability for use. Brine treatments are now carried out on two individual routes on separate Operating Company units and Transport Scotland will look to roll out further treatments following a full review at the end of the current season.

For treatments in extreme cold, Transport Scotland has developed guidance for the Operating Companies on the use of alternative de-icers that work at temperatures below which road salt (sodium chloride) becomes less effective. The guidance advises the trunk road operating companies on the storage, management and application of a range of alternative de-icers. Transport Scotland has obtained stocks of EcoThaw, Safecote and Magnesium Chloride. Experience of using alternative de-icers is being built by trialling enhanced performance specifications for treatments on high altitude sections of the A9.

In Wales a combination of pre-wetted, pre-coated (addition of agricultural by products) liquid and dry salting using either 10mm or 6.3mm salt grading depending on the treatment requirement is used. Welsh Government has be using pre-wetted / pre-coated treatment for over 20 years.

The Use of Maintenance Plant and Equipment – The serviceability of the winter service plant is crucial to the effectiveness of operations. It is therefore essential to operate a well-maintained fleet of spreading vehicles.

There is a vast selection of plant and transport available for highways/roads authorities with which to discharge their winter service responsibilities. The topography and needs of each country and area is unique and it follows that this will create the need for a particular range of equipment in order to fulfil its function and the requirements. The choice in sizse and type of vehicle used depends on the character of the road network and length of salting route.

The current fleet of Highways England vehicles was procured through two companies: Romaquip and Aebi-Schmidt. The Romaquip spreader body is constructed almost entirely from stainless steel. The benefits

of this construction include reduced maintenance and increased operational life. The Aebi-Schmidt vehicle is equipped with a Stratos modular hopper with a powder-coated finish (electrostatic spraying and baking) which is an advantage for work in the harsh winter environment.. A vehicle with stainless steel spreader body is shown below.

Transport Scotland's South West Unit Operating Company Scotland TranServ have implemented further improvements utilising technology to improve winter service decision making and in controlling the application of anti-icing materials using the Schmidt Autologic system to run treatment routes and electronically record the route widths using GPS.

Each route is then programmed into the spreader control box for each permutation of spread rate. The spreader driver selects the combination of route number and spread rate, and spread is controlled by GPS, preventing overspreading by automatically changing spread width at each change on carriageway cross-section, and leaving the driver free to concentrate fully on driving.

Careful consideration is given in regard to resource requirements to react to heavy snowfalls. Purpose built four or six- wheel drive spreading plant is assigned to high ground or routes with significant gradients where increased traction and pushing power are essential in the event of heavy snowfall. Provisions are made for reserve snowploughs to be available to provide additional support and give cover in the event of damage to front-line equipment.

'Vulnerable locations' are identified where the road gradient can make it difficult for HGVs and other vehicles to make progress in wintry conditions. Service providers evaluate the most vulnerable locations within their area and develop various measures, documented within their Winter Service Plans, which they will employ when severe weather is forecast. The measures include additional salt applications during precautionary treatments, special attention during winter patrols, pre-positioning snow ploughs vehicles in advance of snow storms. In addition, enhanced arrangements are put in place with recovery vehicle operators to aid quicker recovery of vehicles in difficulty or clearing incidents.

Where precautionary treatment shall be insufficient to prevent ice or snow remaining on the trunk road, further treatment including salting, ploughing and/or snow blowing is carried out to restore all roads to a

5.1.2 Treatment Matrix Guide

Weather Conditions Road Surface Conditions Road Surface Temperature (RST)	Air Temp	Treatment	
		Dry Salting (g/m²)	Pre-wetted Salting (g/m²) (see Note 1)
Frost or forecast frost RST at or above -2°C (irrespective of dry, damp or wet conditions)		5	5
Frost or forecast frost RST below - 2°C and above - 5°C and dry or damp road conditions (see Note 3 if damp and lightly trafficked)		10	5
Frost or forecast frost RST below - 2°C and above - 5°C and wet road conditions (see Note 3 if lightly trafficked)		15	15
Frost or forecast frost RST at or below - 5°C and above -10°C and dry or damp road conditions (see Note 3 if damp and lightly trafficked and Note 5)		15	15
Frost or forecast frost RST at or below - 5°C and above -10°C and wet road conditions (existing or anticipated) (see Note 3 if lightly trafficked and Note 5)		2 x 15	2 x 15
Light snow forecast < 10 mm		20	15
Medium/heavy snow or freezing rain forecast		2 x 20	See Note 2 and Note 4 below
Freezing rain falling		20 (successive)	See Note 2 below
After freezing rain		20	See Note 2 below
Ice formed (minor accumulations)	above -5°C	20	See Note 2 below
Ice formed	at or below -5°C	2 x 20	See Note 2 below
Hard packed snow/ice	above -8°C	20 (successive)	See Note 2 below
Hard packed snow/ice	at or below -8°C	salt/abrasive (successive)	See Note 2 below

The rate of spread for precautionary treatments may, if appropriate, be adjusted to take account of residual salt or surface moisture.

It has been assumed that two treatments are required to achieve spread rates at or exceeding 30g/m².

Notes:

1) Spread rates for pre-wetted salt is the combined weight of dry rock salt and brine combined at 70:30 proportions by weight respectively with a maximum brine concentration of 23% salt.
2) When ice has formed or snow is falling dry salting is the preferred treatment unless the road is closed to traffic when pre-wetted salting may be used. Pre-wetted salting is the preferred treatment in advance of such conditions.
3) Treatments should be carried out, wherever possible, after traffic has dispersed standing water. Successive half rate treatments (for both pre-wet and dry salt operations) should be considered for lightly trafficked roads at the lower end of temperature bands indicated.
4) For snow covering forecast to exceed 30mm ploughing should be conducted early enough to ensure snow accumulations do not exceed 10mm. The rates in the table are for precautionary salt treatment

ICE AND SNOW CLEARANCE TREATMENT RATES (SOURCE: HIGHWAYS ENGLAND)

TRANSPORT SCOTLAND ICEBREAKER

safe condition and expose the original surface as soon as reasonably practicable. Snow is ploughed when the snow depth exceeds 30 mm. Each pass of the plough is supplemented by the spread of salt in accordance with a treatment matrix such as the one opposite.

Procurement of the Highways England fleet has led to savings in salt usage. This is due to the fact that the fleet has the ability to alter spread rates in 1g/m2 increments. This has allowed the Highways England to adopt a new treatment matrix that works at reduced spread rates to those previously applicable. The treatment rates for ice and snow conditions currently used by Highways England can be seen in the table below.

In severe snow situations highways/roads authorities also make use of snow blowers, which are either self-propelled or de-mountable units. In Scotland where heavy snowfalls are a regular occurrence each year the self-propelled units are essential. The modern blower is powerful and capable of moving a high volume of snow. Transport Scotland recently introduced innovative new equipment including icebreakers, inverted V-ploughs and footway snow blowers.

Calibration of salt spreaders is essential to providing an efficient winter service operation and attention is given to the tests ensuring that each vehicle is achieving the correct spread rate and width of spread within defined parameters. The calibration of equipment is carried out in advance of the expected first frost by Highways England. Transport Scotland vehicles are calibrated twice each winter, in September and again in January. In Wales the vehicles are calibrated once the salt stocks have been replenished and vehicle salt use monitored and where identified vehicles recalibrated through the winter season or where there is a change in anti-icing material being used.

Mutual Aid – Whilst each organisation must prioritise the treatment of their own networks, there are often arrangements between organisations to provide mutual aid. This includes the sharing of plant, labour and salt. One example of this mutual aid in action can be found in Scotland where salt procured by the trunk road service provider is stored by the local authority with good flexible work arrangements. The mutual aid arrangements facilitated the sharing of snow blowers to each other in order to respond quickly to varying weather patterns. In Wales, additional salt stocks are stored by Welsh Government at strategic locations to ensure high levels of resilience are maintained.

Road Weather Information Systems - Accurate prediction of ice and snow is a key factor in facilitating efficient winter service operations, minimising abortive salting works while keeping the network as safe as possible.

Highways/roads authorities make considerable investment in the very latest technology to provide the means for accurate prediction so that appropriate winter action is taken. In England, there are currently 254 weather stations active on Highways England's road network gathering weather data. In Scotland, there are 153 weather stations across Transport Scotland's road network. Transport Scotland also has 50 patrol vehicles equipped with remote accessible mobile temperature sensors and CCTV cameras in spreader vehicles to show real time conditions. The Department for Infrastructure, Roads also has a network of 21 Weather stations and a further 160 CCTV cameras which can be used to monitor the weather. Road weather information systems allow remote monitoring of weather conditions that impact upon the safe operation of road networks in real time. They feed into the production of weather forecasts and provide support to maintenance and operations personnel enabling them to make informed and timely decisions.

A road weather information system typically consists of Environmental Sensor Stations (ESS), commonly referred to as weather stations, and a web based service for the dissemination of information generated by the ESS to its users.

All highways/roads authorities throughout the United Kingdom make use of road weather information systems.

SNOW BLOWER IN USE IN SOUTH WALES

Within Wales the highways/roads authorities share this information between them to ensure the most accurate weather forecast is provided and validated by local weather stations together with the road conditions.

Latest Advances in UK Road Weather Information Systems – Highways England's Weather Information Service

In 2016, Highways England introduced its new Severe Weather Information Service (SWIS). Building on previous system developments that improved the overall provision and frequency of the weather forecasts and weather observations, SWIS combines critical elements for weather information, decision making and treatment activities, and winter fleet activities into a single system. The amalgamation of these services helps Highways England and its partners to manage the risk of severe weather more effectively through improved access to dynamic real-time information, together with delivering technology-based efficiencies.

SWIS delivers an enhanced, consolidated view of information to approximately 2,000 operational users actively working to manage and improve the performance of the road network in advance of and during severe weather conditions, including winter service providers, maintainers and control room staff, and external parties. The system supports better planning, execution and recording of winter treatment actions, improved identification of weather events with a potential impact on the road network, and enhanced rectification of weather and winter treatment equipment faults

The service is supported by a fleet data logging specialist, providing real-time vehicle tracking and route navigation for drivers, to enable Highways England to monitor all treatment activity carried out by the winter maintenance fleet. The solution enables the monitoring of all activity once a vehicle has left a depot and this data is recorded in SWIS to ensure compliance and to inform future planning.

3.3. ASSESSMENT OF THE SNOW & ICE CONTROL MEASURES

Snow & ice control measures are typically included within the winter service plan. Local highways/roads authorities within the United Kingdom work to a 'best value' business principle. A range of performance indicators (PI) are used to monitor winter maintenance.

Examples of performance indicators are:

Objective:	Compliance with response time for leaving the depot
PI:	Number of late departures; 100% compliance expected.
Objective:	Compliance with response times for completing the routes.
PI:	Number of late arrivals; 100% compliance expected.
Objective:	Receipt of the service provider's diary.
PI:	Number of diary entries received after the agreed time limit as a percentage of total winter service diary entries.
Objective:	Receipt of the winter service order.
PI:	Number of orders received after the agreed time limit as a percentage of total winter service orders.
Objective:	Average cost to salt per kilometre.
PI:	Cost per winter service season.

Auditing the service can be undertaken in two different and separate forms. The first is by desktop, through analysing written records such as tachographs, computer printouts (possibly involving GPS), salt diaries, confirmation of call-out, driver training records, quality assurance operating procedure/winter service manual, and salt management records for the individual salting routes. The second is on-site, by carrying out random inspections to check that salt is being placed on the network at the correct time and in the right manner. A comprehensive record must be kept for each audit.

An important part of road weather information systems is to record base data in order to be able to assess the value of the forecasts. In general, it can be said that a road weather forecast has value if a correct decision is

NEW WELSH GOVERNMENT COMBI (SOLID / LIQUID) SPREADER WITH VIEW OF SPRAY BAR AND SPINNER ASSEMBLY

taken which prevents the formation of ice or snow accumulation on roads and/or a correct decision is taken which prevents the use of unnecessary de-icer applications. However, assessing value is complicated by external factors such as the residual de-icing chemical on the road and political considerations, which can bring about unnecessary treatments.

In order to judge the value in a forecast it is best to look at forecasts of road frost. This is usually done using a 2x2 contingency table, which compares the forecast against the actual.

By assigning financial values to these contingencies it is possible to derive a measure of value from the forecast. Using the contingency table there are a number of derived variables which can be produced:

- Percentage correct;
- Probability of detection;
- False alarm rate;
- Frost frequency

Two by two contingency table

	Frost forecast	**No frost forecast**
Frost occurred	Protection cost: (F/F)s	Damage cost: (NF/F)s
No frost occurred	Protection costs: (F/NF)	Correct rejection: (NF/NF)

Transport Scotland has introduced an extended trial of the ITD Storm Performance Index which analyses data coming back from each of its Road Weather Information Systems (RWIS). It usetilises readings from non-invasive road surface state sensors using three lasers to determine the layer thickness of iIce, wWater and fFrost/sSnow independently. These values are then combined into an index called Grip which shows how the friction level of the road surface has deteriorated due to the weather affecting the road surface.

Following upgrade of eight road weather stations on the Transport Scotland trunk road network in 2014, data suitable for analysis of treatment effectiveness utilising the Idaho Storm Performance Index has been possible over the past three winter seasons. The eight sites were chosen to represent two clear climatic areas.

The information provides a clearer indication of the saving made through current levels of investment in winter maintenance activities and provided an understanding of both individual event performance as well as macro level network details.

3.4. Traffic safety and information

Contact through the traditional and more modern media is important as a means of keeping the road user informed of adverse conditions and promoting safety on the highway.

Through this contact with the community and road users, the operations are more effective, better understood and promote a positive interchange of views with the public. Highway/roads authorities therefore make use of several means of communication which include:

- Leaflets on ways motorists can help to improve road safety;
- A plan of the spreading network;

vPress releases relating to winter service and particular highway incidents;

- Press articles;
- Press/radio/television interviews;
- Information passed through motoring organisations and local radio stations;
- Information and advice on highway/road authority websites;
- Information on variable message signs both in advance of and during severe weather;
- Information passed through social media networks

HIGHWAY/ROADS AUTHORITIES' USE OF SOCIAL MEDIA

such as Facebook and Twitter; and

- YouTube videos to explain how winter service is delivered.

Many highway/road authorities provide information and advice to the road user through their websites, which includes details of priority treatment routes and advice on preparing for the winter. In recent yearsyears, the use of social media networks for the dissemination of information to the road user has grown. In terms of adverse weather, Highwayhighway/roads authorities are making use of their Twitter and Facebook pages to inform road users of spreaders on the road and also to warn of forecast adverse weather conditions.

For the English Trunk Road Network, weather and road condition information is distributed to the media and Highways England customers from Highways England's National Traffic Operations Centre (NTOC) in Birmingham. During the winter months, weather forecasters are stationed in the NTOC to ensure that Highways England can provide early warning of severe weather and give targeted advice about safe driving and road conditions regionally or nationally as appropriate.

Highways England provides the management team, Ministers ministers and the Press Office with information on the state of the network and weather-related incidents. SWIS also ensures that adjacent service providers, local authorities, police, and Highways England area teams are aware of winter service decisions. The service providers have a minimum requirement to report on the state of the network and treatment decisions at 10:00 and 16:00 each day. In addition, the service providers are to give an assessment of the weather forecast and their intended winter service action for the weekend before 16:00 on Friday.

Snow blower in use in South Wales

Following the successful introduction of a salt management facility in previous versions of Highways England's web based system, these functions have been delivered within SWIS all highways authorities in England use this so that a national overview of salt stocks can be derived. This live, reliable and accurate stock reporting is an aid to both the authority and the salt supplier.

In Northern Ireland, summary information on winter service salting activities is relayed electronically to the broadcast media for public distribution. Information is also relayed through the public facing traffic information website TrafficWatch to ensure that the latest news on road conditions is available to motorists prior to peak travel periods.

Transport Scotland's winter response is co-ordinated from the control centre for Traffic Scotland, the national ITS (Intelligent Transport System). It is controlled and operated from a purpose -built control centre, ope-

SNOW BLOWER IN USE IN SOUTH WALES

ned in 2013, at the existing Forth Road Bridge, ideally located for optimal management of the existing bridge and the new Forth Replacement Crossing, which will be opened in 2017.

In Scotland, the daily winter action plans are being made publicly available on the Traffic Scotland website. The information goes live at 3pm each day following receipt of the forecast. The action plan information tells people where the salt spreaders will be at what time and how much salt they will be spreading.

In 2016 Transport Scotland further enhanced the information available to the public when it launced the Gritter Tracker service on the Traffic Scotland providing live tracking of the Trunk road Winter fleet across Scotland.

Transport Scotland working in partnership with the Scottish Police has developed a severe weather information strategy to warn and inform road users when significant disruption to the road network is expected during extreme weather. The advice and information service is instigated when severe weather is forecast within Scotland. Forecast information will be provided in advance of, and during, any severe weather event.

Travel advice issued is aligned to four specific risk categories, with the appropriate warning issued based upon the anticipated severity of conditions described within the weather forecast. The four levels of advice are:

- Stage 1 Normal operations - No severe weather
- Stage 2 Travel with caution - Police are advising travellers that conditions for road travel are hasardous hazardous and drivers should exercise extra caution
- Stage 3 High risk of disruption for road journeys - Police are advising that conditions for travel are extremely poor and there is a high risk of disruption for road journeys. Travellers are likely to experience significant delays
- Stage 4 Avoid travelling on the roads - Police advise drivers to avoid travelling on the roads. Travellers will experience severe delays of several hours or more.

This advice is provided to road users through Transport Scotland's network of Variable Message Signs, the Traffic Scotland website, radio travel information broadcasts and the Traffic Scotland Customer Careline to help them play their part during extreme weather events.

The Scottish Multi Agency Response Team (MART), a group of partners that work together to improve the quality and timing of transport information, co-ordinates the flow of information between agencies and the public. A Met Office representative works in MART to ensure that any changes to the severity or areas affected by severe weather can be updated and provided to the public. The MART consists of Traffic Scotland, Transport Scotland, the Met Office, the operating companies, Network Rail, First Scotrail, Confederation of Passenger Transport, Police Scotland, and the Society of Chief Officers of Transportation in Scotland. Other ways in which Transport Scotland makes information available to the public include:

- The provision of CCTV camera images on its website, enabling road users to check current conditions on the network before setting out on their journey.
- The Traveline app for smart phones.

In Wales, the Welsh Government promotes the service providers to develop effective liaison and communications with Police, media, emergency services, public transport operators, freight transport, and haulage and automobile associations directly in order to avoid extended chains of information. A Traffic Management Centre is located in North and South Wales, and through "Traffic Wales" the public is informed of traffic and road conditions and can access live CCTV images. Where there is an impact on the operation of the motorway or trunk road network as a result of weather or incidents the most up to date information is available.

During severe weather conditions the Traffic Management Centre facilities are utilised to coordinate and manage winter service activities and liaise with other highway authorities.

3.5. LOCAL COMMUNITY COLLABORATION

Many local authorities have taken steps to collaborate with local communities in the delivery of certain aspects of winter service. Examples of this collaboration include the provision of salt/grit bins in locations that are not on treatment routes or where a particular hasard has been identified. The public are able to access these bins for use in the community on public roads and pavements. This can be particularly useful for 'joining up' treatments from the main road carried out by cCo-

unty cCouncil spreader vehicles to smaller access roads. Norfolk County Council can be used as one example of this scheme in action. They first implemented the sponsorship and provision of salt/grit bins through pParish, tTown, dDistrict and bBorough cCouncils in 2010. By 2012, Norfolk had a total of 1500 salt/grit bins available around the county for public use.

Some local authorities have commenced Snow Champion schemes. Champions are provided with the correct equipment and guidance on how and when to clear footways. There is no contractual relationship with the Snow Champions and this is on a purely voluntary basis. An example of this scheme can be found in Cumbria County Council, who during the 2012/13 winter season, were aiming to recruit up to 300 volunteers (around 50 in each district) to help clear snow and ice from footways and pavements near their homes.

A similar scheme used by other County Councils involves the recruitment of town and parish councils to help keep paths and pavements clear during the winter. Town and parish councils are provided with salt free of charge, and free training courses for the safe operation of clearance of snow and ice from footways. In return the town/parish council are asked to provide details of footways treated using the free salt provided, identify a 'Snow Warden' to co-ordinate activities locally and provide information to the cCounty cCouncil about local conditions, and someone who has the authority to order the refilling of bins on behalf of the parish/town council.

Other local authorities have contracted out snow clearing work in isolated villages, industrial areas and schools not on treatment routes to farmers and other large vehicle drivers as part of a tendering process to

COUNTY COUNCIL SUPPLIED SALT/GRIT BIN

SNOW CLEARANCE BY A FARMER ON A MINOR ROAD

provide added capabilities during instances of severe weather. One of the benefits of using those from local communities to assist with treatment is the local knowledge they have of the roads that need treating the most in their communities.

Suffolk County Council has contracts with over 200 farmers (and other contractors) and Kent County Council has arrangements with approximately 180 farmers across the county, who assist in snow clearance when needed. Many other County Councils have similar numbers of arrangements with farmers. An example of how this works in practice can be seen at Norfolk County Council. A mixture of modified ploughs supplied by the County Council and farmer owned ploughs are used to enable the clearance of snow on minor roads that are not on priority routes. Farmers receive start of season training/briefings on how to undertake the activities and all equipment is inspected by the county council prior to the start of the winter season to ensure it is in a safe and working order.

4. ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1. THE NATIONAL WINTER SERVICE RESEARCH GROUP

The NWSRG is a members group dedicated to advancing understanding of best practice for winter service delivery, taking the best from currently available knowledge and supplementing any gaps with new knowledge and research. It is supported by experts from the winter service industry and government bodies. The NWSRG Steering Group is a Technical Sub-Group of the UK Roads Board. In turn, this is part of the UK Roads Liaison Group family of organisations.

The NWSRG provides oversight and liaison for the development of guidance and new knowledge for the UK public roads sector, with the NWSRG Practical Guide for Winter Service now providing the national guidance on winter service in the UK and promoting its use amongst highway authorities. It has also developed a syllabus for training winter service decision makers, based on the Practical Guide.

Improvement is an ongoing process and there has been a process of review and updating of the guidance to take on board feedback and comments from practitioners and to ensure consistency with the new risk based approach advocated in the UK Code of Practice 'Well-managed Highway Infrastructure. Some key changes include new, and simpler, spread rates tables. The guidance relating to factors such as traffic levels and wind speed is also being updated and revised. As part of the update, additional supporting information is also being introduced. For example, it may be useful for an authority to be able to demonstrate that the spread rates they utilise have 'safety factors' built in to account for expected losses over time, and that the actual amount of salt required on a road surface to prevent ice from forming at any particular time is not that great. A working group have also been reviewing the calibration guidance, including new photographs and guidance videos being added to help practitioners readily understand and undertake the calibration and monitoring process, including crucially an assessment of the salt distribution. The new national code Well-managed Highway Infrastructure places more emphasis on using a risk-based approach and the Practical Guide will incorporate how this approach should be applied to winter service

The group are considering the key areas for future research, with potential topics under consideration including research and advice on residual salt, both how to measure and it's longevity. This will inform guidance for practitioners when retreatment is necessary. Another area for development is how risk based decision making can be applied to winter operations, including guidance that will clearly link to information presented by weather forecasters.

The group are also considering if its remit should be extended to cover other severe weather events apart from snow and ice. Many winter practitioners are already involved in responding to these emergencies in addition to their winter service responsibilities and the NWSRG has strong links with the Environment Agency and Met Office, whose expertise would be essential to delivering the guidance.

4.2. ADVANCES IN SPREADER TECHNOLOGY

Since the mid-1990s organisations throughout the United Kingdom have been seeking to reduce salt usage through the integration of new technologies, such as global positioning system (GPS), geographical information systems (GIS), digital radio communications and forecast thermal mapping. Experimentation through recent research and development projects in the United Kingdom has demonstrated that selective salting is both possible and desirable. The possibility to start and stop spreading also provides the possibility of varying the spread rate along the route in accordance with the forecast thermal map temperatures. The next logical step would be to provide real-time weather data captured by the vehicle as it travels along the route and this is now possible through the spreaders reading and recording road surface temperatures whilst carrying out their route.

Highways England's winter fleet in England is equipped with a data logging capability which provides a facility for real time data capture. The amount of salt spread, spread width, material type, time taken to complete the route, and, fuel usage are examples of some of the elements that data logging can capture. The latest GPS technology also help drivers to accurately execute winter service activities through provision of in-vehicle software, meaning turn by turn guidance is readily available to ensure efficient treatments.

The use of data logging further aids Highways England and its Service Providers to monitor salt usage and spreader driver behaviour, thus improving the sustainability of the winter service provided.

Another benefit of the data logging technology comes in the form of protection against claims from third party motorists. This is a key issue for Highways England and data logging provides robust evidence to strengthen the defence against claims as data logging can pinpoint a vehicle's location at any moment in time.

UNITED KINGDOM

4.3. ALTERNATIVE MATERIALS

As part of the drive to reduce salt usage Highways England is looking at the suitability of brine only treatments. Brine is particularly suitable for precautionary treatments on marginal nights which can be typical due to the weather patterns in much of the United Kingdom. The economical and social impact of winter treatments is being assessed by trials to measure the corrosive effect of various de-icers on highway assets. In addition, work into the environmental effects of winter treatments also continues.

Much of the ongoing work on the use of alternative materials in the UK is based around the need for intelligent application of treatment materials to best fit the environmental conditions of the location it is applied.

This also extends to the geopolitical environment. For example, Norfolk County Council undertook trials using alternative liquid de-icers on priority footways using a drop sprayer mounted on a small grounds maintenance vehicle. The purpose of the trials was to reduce the number of complaints about tracking rock salt into shops and to provide a more effective treatment on footways at lower temperatures. Trials proved effective preventing the formation of ice in low temperatures experienced during the 2010/11 winter season, and also resulted in fewer complaints from shopkeepers.

4.4. RESIDUAL SALT MEASUREMENT

Within the United Kingdom research is ongoing into measuring residual salt on the road surface. Currently road inspections confirm whether there is sufficient residual salt on the road to deal with the current conditions. There is a great possibility in the future that the measurement of residual salt on road surfaces might take place through intelligent systems.

4.5. MOBILE CONDITION SENSORS

In Scotland, four winter spreader vehicles used to patrol the M8 utilise a mobile condition sensor that monitors pavement condition - grip and pavement temperature in real time. The data is displayed on a smart phone on the dashboard of the vehicle or transmitted via the phone's mobile network to road weather management software for viewing by others at a central control room.

It provides information that can be used to complement existing fixed weather stations allowing the patrol driver and winter duty personnel to make better informed decisions on the need to carry out ad-hoc treatments on the network.

5 References

[1] Transport Statistics for Great Britain (TSGB) 2012;

[2] Northern Ireland Transport Statistics 2003-2004; Transport Statistics Scotland 2003

[3] Section 41 (1A) of the Highways Act, 1980; Section 111 of the Railways and Transport Act 2003; Section 150 of the Highways Act 1980

[4] Section 150 of the Highways Act 1980

[5] In Scotland, the terminology used is 'road' instead of 'highway'.

[6] Section 34 of the Roads (Scotland) Act 1984

UNITED STATES Version 2014

1 DEMOGRAPHICS AND ROADS

1.1 INFORMATION ABOUT THE COUNTRY

The United States of America is a federal system with 50 states, the District of Columbia, and numerous local governments within each state. The Federal Highway Administration (FHWA), within the national executive branch, neither operates nor builds highways, but administers over $26 billion per year of federal-aid highway funds to states and localities, primarily for capital expenditures. The total expenditure for highways is over $118.3 billion per year, mostly funded by state and local governments (3).

The total area of the United States is over 9.1 million square km. More than 81% of this land (or 7.4 million square km) is in snowy regions, which receive more than 13 cm of average snowfall per year. The population of the United States exceeds 304 million people (17). Nearly 71% of Americans (or more than 215 million people) live in snowy regions.

Area	Total	9,161,979 km^2
	Snowy regions	7,447,614 km^2
Population	Total	304.06 million
	Snowy regions	215.79 million
Road Length	National Highway System	262,809 km
	Snowy regions	195,626 km
	Other Federal-Aid Hwys	1,320,998 km
	Snowy regions	958,957 km
	Non Federal-Aid Hwys	4,900,125 km
	Snowy regions	3,678,426 km
	Total	6,483,932 km
	Snowy regions	4,833,010 km
Latitude (capital)		39°N

1.2 ROAD NETWORK AND TRAFFIC

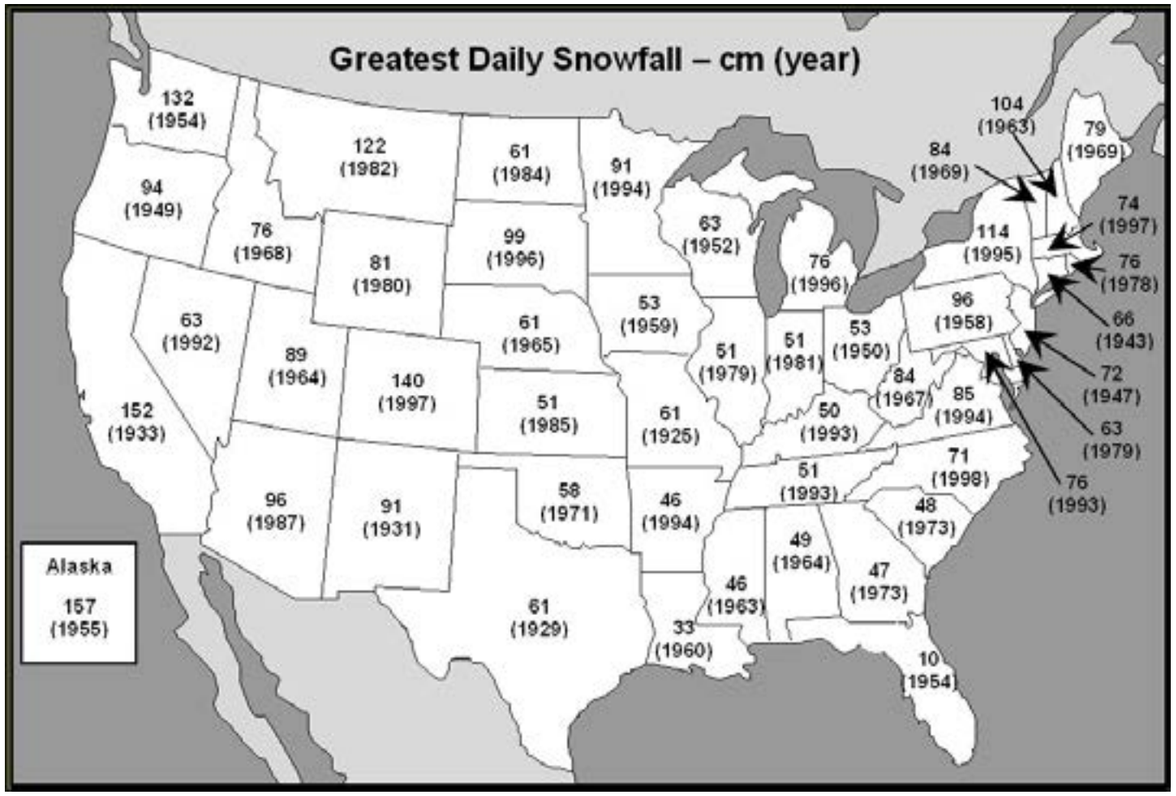
The road network consists of more than 6.4 million km of highways. Over 262,000 km of the road network are part of the National Highway System, which is comprised of interstate expressways and primary roads. There are over 1.3 million km of other federal-aid highways and more than 4.9 million km of non-federal-aid highways. On average, each vehicle travels more than 19,300 km each year. Nearly 235 million passenger vehicles (cars and light trucks) use U.S. highways to commute to work, for personal business, or for recreational travel (3). More than 3 million commercial vehicles use the highways, with about 1.1 million being long-distance freight haulers (10).

Winter weather has a significant affect on traffic flow, road safety, and agency productivity. It has been estimated that 23% of the non-recurrent delay on highways across the nation is due to snow, ice, and fog. This amounts to an estimated 544 million vehicle-hours of delay per year. Snow-covered and icy pavement also caused significant delay. Each year, approximately 2,200 people are killed in crashes during snowfall and sleet or in crashes on pavement covered with snow, slush, or ice. Approximately 192,500 people are injured in these crashes annually. Winter road maintenance accounts for roughly 20% of state transportation agency maintenance budgets. Each year, state and local agencies spend more than $2.3 billion on snow and ice control operations (2).

2 CLIMATE

2.1 OVERVIEW OF CLIMATIC AREAS

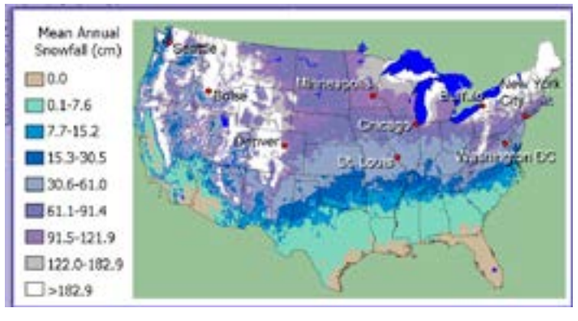
The United States has a variety of climates due to significant terrain differences, its proximity to large wa-



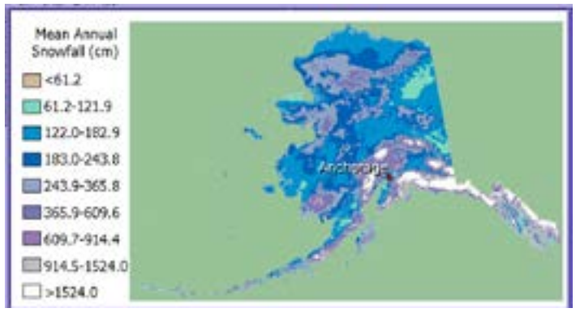
GREATEST DAILY SNOWFALL MAP

ter bodies and a large land area between its northern border and the Polar regions that allows arctic air to migrate south in the winter with minimal moderation. The 48 contiguous United States (CONUS) are climatically different from the northern State of Alaska, and the semi-tropical State of Hawaii in the Pacific Ocean. The snow extremes in the CONUS, depicted in the Greatest Daily Snowfall map, are primarily in mountainous areas with low population densities and few roads, but with many critical mountain passes. There are large metropolitan areas in all regions. However, the Northeast and Midwest have both large populations and considerable snowfall due to lake effect snow and coastal cyclones.

As shown in the Mean Annual Snowfall maps, geographical factors create large differences in average snowfall. Most states experience significant snowfall. The exceptions are located along the southern tier of the CONUS along the Gulf coast, the southwestern deserts, the Pacific coast and Hawaii. Ice without snow can also form on roads, especially in more temperate and coastal areas.



CONUS MEAN ANNUAL SNOWFALL MAP



ALASKA MEAN ANNUAL SNOWFALL MAP

2.2 STATISTICS ON TEMPERATURE AND PRECIPITATION

Table 1 lists temperature and precipitation statistics for the 10 U.S. cities depicted on the Mean Annual Snowfall maps (9).

Location	Normal Daily Minimum Temperature (Degrees C)				Normal Monthly Snowfall (cm)				Normal Annual Snowfall (cm)	Normal No. of Days: Snowfall >2.5 cm	Max. Snowfall in 24 hours (cm)	Max. Snow Depth (cm)
	Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar				
New York, NY	-0,2	-3,2	-2,2	1,7	6,6	20,6	19,3	8,1	56,9	6	67,1	55,9
Buffalo, NY	-4,7	-7,9	-7,4	-3,3	64,8	66,3	45,2	9,1	246,4	27	96,3	111,8
Washing-ton, DC	0,0	-2,6	-1,3	2,9	3,8	15,7	13,2	4,1	38,6	4	47,5	55,9
Chicago, IL	-6,4	-9,8	-7,1	-1,9	22,1	28,7	21,1	15,2	96,5	12	47,2	71,1
Minneapo-lis, MN	-11,7	-15,4	-11,2	-4,7	25,4	34,3	20,8	26,4	142,0	17	53,3	96,5
Saint Louis, MO	-3,4	-6,0	-3,1	2,3	12,4	18,8	12,2	8,4	57,2	6	35,3	50,8
Denver, CO	-8,7	-9,3	-7,2	-3,7	22,6	19,6	16,0	29,5	154,9	18	59,9	158,0
Boise, ID	-4,4	-4,7	-1,8	1,1	16,3	12,4	8,4	3,8	49,5	7	33,0	33,0
Seattle, WA	2,2	2,2	2,9	3,9	6,4	6,1	3,3	1,5	20,6	3	54,4	53,3
Anchora-ge, AK	-11,4	-12,6	-7,7	-1,8	37,8	22,9	27,9	26,2	176,5	20	55,9	2,301,2

2.3 WINTER INDEXES USED IN THE COUNTRY

The Washington State DOT uses a frost index, which is a winter index without a snowfall factor. The frost index is related to performance measures for snow and ice control strategies. When the winter road maintenance budget is exceeded, the DOT plans to use the frost index to help justify requests for additional funding.

The Wisconsin DOT uses a winter index with five weather factors including snow events (SE), freezing rain events (FR), snow amount (AMT), storm duration (DUR), and incidents (INC) such as drifting, cleanup, and frost runs. The Wisconsin winter index is used to classify the type of winter and to evaluate expenditures and performance.

$$WI = 10 * \frac{SE}{63} + 5.9 * \frac{FR}{21} + 8.5 * \frac{AMT}{314} + 9.4 * \frac{DUR}{1125} + 9.2 * \frac{INC}{50}$$

The Kansas DOT and the Minnesota DOT have adopted a winter index developed by the Strategic Highway Research Program (SHRP). Weather factors in the SHRP index include mean daily snowfall (S), pro-

$$WI = 0.71839 * Frost + 16.87634 * FreezingRain + 12.90112 * Drifting - 0.32281 * Snow + 25.72981 * SnowDepth + 3.23541 * Hour - 2.80668 * AverageTemperature$$

portion of days with air frosts (N) (that is, days with maximum air temperature at or below 0 °C), temperature range (R), and an average daily temperature index (TI). The temperature index is 0 if minimum air temperature is above 0 °C, 1 if maximum air temperature is above 0 °C while minimum air temperature is at or below 0.

$$WI = a(TI)^{0.5} + b\ln(\frac{S}{10}+1) + c\frac{(N)^{0.5}}{R+10} + d$$

3 WINTER ROAD MANAGEMENT

3.1 STANDARDS AND RULES

Because of the allocation of maintenance to state and local governments, there is no national policy for winter road maintenance in the U.S. State and local governments may operate their own maintenance equipment, hire contract services, and establish their own Level of Service (LOS) goals. Level of Service may be based on pavement condition goals, traffic levels, or customer satisfaction. Winter road maintenance efforts vary based on climatic conditions, agency resources, and roadway characteristics. Higher classes of highways generally receive more attention. Routes on the National Highway System are typically cleared more completely and quickly. Critical areas like mountain passes may have snow-chain requirements for vehicle tires, and many local streets are designated "snow emergency routes" that must be cleared of parked cars during snow events.

FIXED ANTI-ICING SPRAY SYSTEM
(PHOTO COURTESY OF CRYOTECH DEICING)

In the United States, winter road maintenance involves controlling snow and ice through mobile techniques or fixed systems. Mobile snow and ice treatment strategies include plowing snow, spreading abrasives (such as sand, ash, and crushed stone) to improve vehicle traction, and dispensing anti-icing/deicing chemicals to lower the pavement freezing point and minimize bonding of snow and ice to pavement surfaces. These strategies are often used in combination. In regions with heavy snowfall, maintenance managers may also erect snow fences adjacent to roads to reduce blowing and drifting snow. (13)

Surveys by the American Association of State Highway and Transportation Officials (AASHTO) Lead States Program have found that nearly 40 states use anti-icing strategies. In addition to mobile anti-icing/deicing operations, 23 states have deployed fixed anti-icing/deicing systems on bridges, sharp curves, and other locations prone to icing (15). These fixed systems typically consist of a controller, tanks, pumps, conduits, and nozzles that dispense anti-icing chemicals on a predetermined area of pavement. Chemical applications can be activated manually or automatically based on Environmental Sensor Station (ESS) data.

Several types of snow and ice control materials are used in the U.S. including solid chemicals (dry and prewetted), liquid chemicals, abrasives, as well as abrasive and chemical mixtures. Chemicals used include sodium chloride, calcium chloride, magnesium chloride, calcium magnesium acetate, potassium acetate, calcium acetate, and magnesium acetate; with sodium chloride being the most prevalent. Snow and ice control material application rates depend on conditions (such as weather, pavement, and traffic) at the time of treatment and on how conditions are expected to change prior to the next treatment (15). Abrasive application rates range from roughly 140 kg to 419 kg per lane km with the average being approximately 224 kg per lane km. Application rates for solid and liquid chemicals vary based on pavement temperature ranges, dilution potential, and ice-pavement bonding. The National Cooperative Highway Research Program (NCHRP) has developed general guidelines on the use of treatment materials and application rates (7).

Highway Maintenance Concept Vehicle

Solid treatment materials are often applied to roads by maintenance vehicles equipped with spreaders, which typically dispense free-flowing granular materials across a width ranging from of one to twelve meters. In many cases spreader operation is automatically adjusted based on vehicle speed. Liquid treatment chemicals are usually applied with vehicle-mounted spinners or spray nozzles. Different types of hydraulic snowplows are used including one-way front plows, reversible plows, deformable mouldboard plows, underbody plows, side wings, and plows designed specifically for slush removal. (15)

Several states have demonstrated and tested advanced winter maintenance vehicles and new maintenance vehicle management systems (15). Snowplows equipped with environmental sensors, as well as Automated Vehicle Location (AVL) and Global Positioning System (GPS) technologies are being used to monitor air and pavement temperatures, observe pavement conditions, track vehicle locations, monitor vehicle systems (such as plow position, material application rate), and monitor road treatment activities. Central computers provide map-based displays for managers who can plan treatment strategies, monitor winter maintenance operations, or conduct post-event analyses. Central managers can also communicate with plow drivers via in-vehicle devices with integrated display and communications capabilities. Thirteen state agencies equip a portion of their snowplow fleet with AVL/GPS technologies and sensors to track distribution of chemical treatments (18).

Other advanced snowplow technologies include heads-up displays that delineate the roadway when visibility is reduced by fog or blowing snow. These technologies can help snowplow drivers determine their lane position, warn of objects and obstacles in front of and behind the vehicle, and increase safety by reducing the frequency of snowplow-related crashes. (15)

3.2 ORGANIZATION AND OPERATION OF WINTER MAINTENANCE

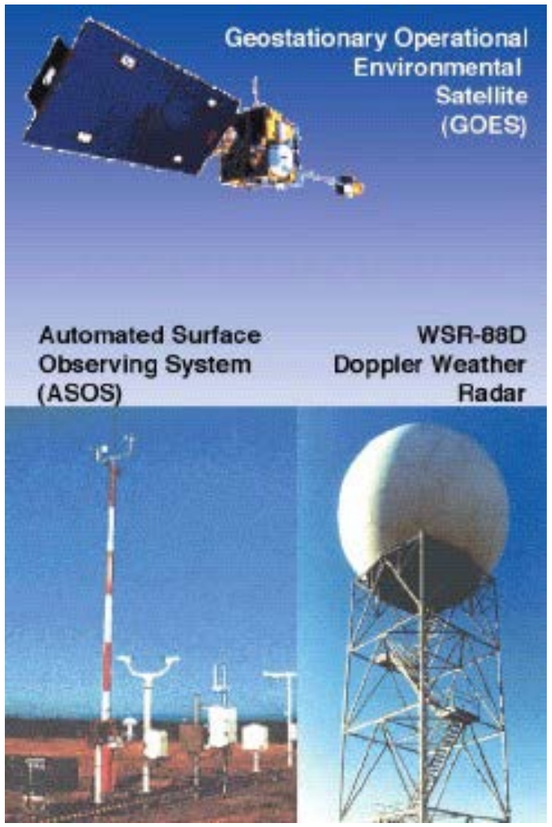
In the United States, winter maintenance is decentralized since roads are owned and operated by state and local agencies. State and local governments fund and perform snow removal and ice control activities or contract with private entities for these services. State and local capital expenditures for roads are more than $57.5 billion annually. Maintenance and operations are over $31.8 billion, of which costs for winter road maintenance are over $2.7 billion per year (3). One third of winter road maintenance expenditures are for treatment materials (10).

Regional differences between average and extreme snowfall create differences in how road maintenance agencies respond to winter weather, from continual and routine treatment to occasional and emergency response for infrequent events. In some states, maintenance agencies coordinate with traffic management agencies to close roads during snow and ice control operations, impose lower speed limits during inclement weather, or restrict travel to vehicles with snow tires or chains (13).

The 50 states coordinate through AASHTO's Snow and Ice Cooperative Program (SICOP) for implementation of advancements and training. SICOP has developed an interactive Road Weather Information System (RWIS)/Anti-Icing training program. This computer-based program consists of seven lessons including Introduction to Anti-Icing and Winter Maintenance, Winter Road Maintenance Management, Winter Roadway Hazards and Principles of Overcoming Them, Weather Basics, Weather and Roadway Monitoring for Anti-Icing Decisions, Computer Access to Road Weather Information, and

Anti-icing Practice in Winter Maintenance Operations. The national training program is being used by 90% of Snow Belt states, the Association of Public Works Association (APWA) and the National Association of County Engineers (NACE). In April 2003, both generic and customized versions of the computer-based training program were distributed to users. Customized versions are tailored to the specific methods, equipment, policies and procedures, and chemicals used in a specific state. (15)

Maintenance personnel use road weather information to assess the nature and magnitude of environmental threats, make decisions about road treatment strategies, and manage resources (that is, staff, equipment, and materials) (13). State and local agencies use various sources to obtain road weather observations and forecasts including the National Weather Service (NWS), private sector meteorological service providers,



Environmental Observing Technologies

RWIS, and thermal mapping. The NWS is a federal agency operated under the National Oceanographic and Atmospheric Administration (NOAA). The NWS is chartered with weather forecasting; issuing storm warnings; disseminating weather and flood warnings for the benefit of agriculture, commerce and navigation; and taking meteorological observations to record the climatic conditions of the United States. In practice, the NWS provides general weather information and warnings for public safety. NWS products include observations from surface sensors (such as ASOS), Doppler radars, geostationary and polar satellites; national forecasts and numerical model guidance from the National Centers for Environmental Prediction (NCEP); as well as regional forecasts and warnings from 125 Weather Forecast Offices and 13 River Forecast Centers.

Generally, the observations provided by the NWS are inadequate for characterizing details of the road environment such as pavement conditions and localized visibility conditions. Because it is not the mission of the NWS to provide customized forecasts to support operational decision making, tailored road weather information is typically provided by private VAMS who are contracted for route-specific "nowcasting" and forecasting services.

NOAA has embraced surface transportation weather by establishing a Surface Weather Program in its Commerce & Transportation Goal Team, a component of the agency's budgeting process. Additionally, NOAA has added Surface Transportation Weather to its strategic plan. Under this goal, NOAA is partnering with the FHWA Road Weather Management Program to improve safety and make more efficient the movement of people and goods on the Nation's highways. In 2007, NOAA and FHWA conducted the 3rd National Surface Transportation Weather Symposium to provide a forum for members of the surface transportation operations, research, and user communities to work together to enhance collaboration and partnerships to improve surface transportation weather products and services for those individuals who use, operate, and manage the United States' surface transportation infrastructure (11).

The FHWA has been active in trying to integrate observations from state-owned Environmental Sensor Stations (ESS) with NWS surface observations. ESS are deployed along roadways and other transportation facilities to provide their agencies with observations of

ESS OWNED BY STATE TRANSPORTATION AGENCIES

surface weather and pavement conditions. Most ESS are deployed as the field components of RWIS (16). RWIS has been widely used in the United States since the late 1980s. Currently, there are nearly 2,500 ESS in the U.S. Over 2,000 of these are part of state-owned RWIS. Central RWIS hardware and software collect field data from numerous ESS, process data to support various operational applications, and display or disseminate road weather data in a format that can be easily interpreted by a decision-maker. (2)

ESS owned by State Transportation Agencies

Maintenance personnel can also use thermal mapping to obtain information on pavement temperatures. Thermal mapping involves use of infrared sensors (hand-held, vehicle-mounted or satellite-based) to create thermal profiles of road surfaces. Measurements are taken under various environmental conditions. Several states, including Washington, Nevada, and Minnesota, have created thermal maps of highway segments. Thermal mapping data have been used to optimize siting of ESS, predict pavement temperatures in locations without ESS, and plan winter road treatment strategies. (4)

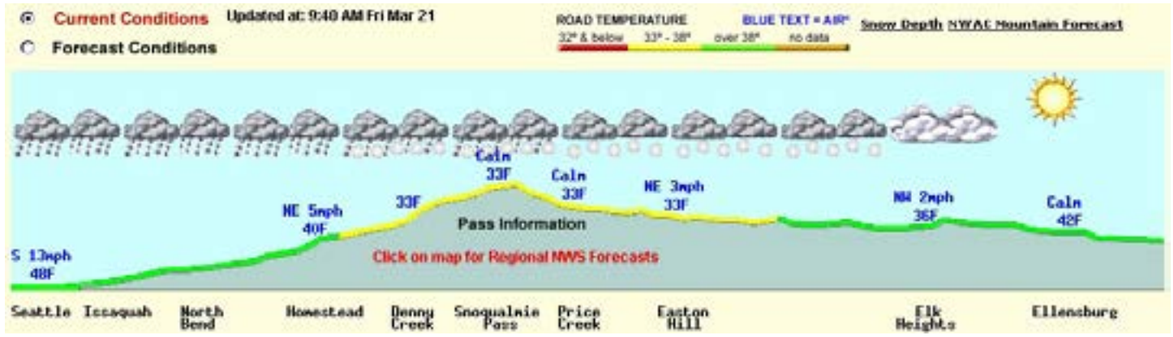
3.3 ASSESSMENT OF THE SNOW AND ICE CONTROL MEASURES

Some states have embraced the concept of performance standards to assess winter maintenance activities (12). Some agencies conduct post-storm evaluations of treatment effectiveness (such as pavement friction measurements) to identify modifications or improvements in treatment strategies (4). Post-season assessments can be used to modify routing and determine changes in personnel and training procedures or equipment and material needs. As part of a project to develop Guidelines for Snow and Ice Control Materials and Methods, the NCHRP developed a pavement snow and ice condition index to evaluate the effectiveness of winter maintenance strategies. The index was used to evaluate the Level of Service achieved by treatments during and after winter storms (7). Different performance measures have been used across the United States with varying degrees of success. There are no widely accepted measures applicable to different roadway classifications and storm characteristics. The NCHRP plans to conduct additional research to evaluate potential performance measures and identify or develop appropriate measures of performance for all roadway classifications and storm characteristics (9).

Some benefits of snow and ice control operations have been quantified. Winter maintenance activities have improved safety by reducing crash frequency and minimizing risks to field personnel and motorists. Roadway mobility is improved when accumulated snow and ice are removed and the number of road closures is minimized. U.S. maintenance managers indicate that effective anti-icing and pre-wetting strategies reduce sanding applications by 20% to 30%, decrease chemical applications by 10%, and reduce chloride and sediment runoff in local waterways. Evaluation data show that anti-icing programs can lower snow and ice control costs by 10% to 50% and reduce crash rates by 7% to 83%. Analysis of fixed anti-icing systems deployed on bridges in Utah, Minnesota, and Kentucky found crash reductions from 25% to 100%. With more efficient application of anti-icing chemicals and abrasives, reduced maintenance costs, reduced delay, and increased safety; benefit-to-cost ratios for RWIS and anti-icing strategies range from 2:1 to 5:1 (18).

3.4 TRAFFIC SAFETY AND INFORMATION

In addition to supporting winter maintenance decisions, ESS data are used by traffic managers to modify traffic signal timing, activate automated motorist warning systems, vary speed limits, close roads, and disseminate traveler information (13). Almost half of all



WEATHER AND PAVEMENT TEMPERATURE INFORMATION ON WASHINGTON STATE DOT WEB SITE

states (i.e., 24) use ITS technologies to manage traffic diversions in response to road closures due to weather events. The same number of states use ESS to determine the need to implement temporary restrictions on vehicles. Eight states use variable speed limits to respond to weather conditions (17). Traffic managers provide travelers with road weather information through dynamic message signs, highway advisory radio, Web sites, and 511—the national traveler information telephone number. The Internet is the medium most commonly used by state agencies to disseminate roadway conditions and weather forecasts on a statewide basis; 37 distribute weather information via Web sites and 35 distribute it via 511 (1). Twenty-nine states distribute weather information on dynamic message signs and 20 states use highway advisory radio. According to a 2006 survey of the country's 108 largest metropolitan areas, 49 metropolitan areas reported using DMS to disseminate weather advisories (18). The Washington State DOT has an advanced web site that includes integrated displays of weather and pavement conditions.

Road weather information is more important to travelers than construction information, traffic conditions, travel times, public transit information, or incident information. A public opinion survey found that weather-related and road surface conditions were most frequently identified as important elements for a 511 service. Forty percent of respondents identified weather and road conditions as most critical (10). Evaluation data show that 80% to 94% of motorists who use traveler information Web sites think road weather information enhances their safety and prepares them for adverse road weather conditions (18).

4 ON-GOING RESEARCH AND STUDIES TO IMPROVE WINTER MANAGEMENT

4.1 NEW TECHNOLOGIES

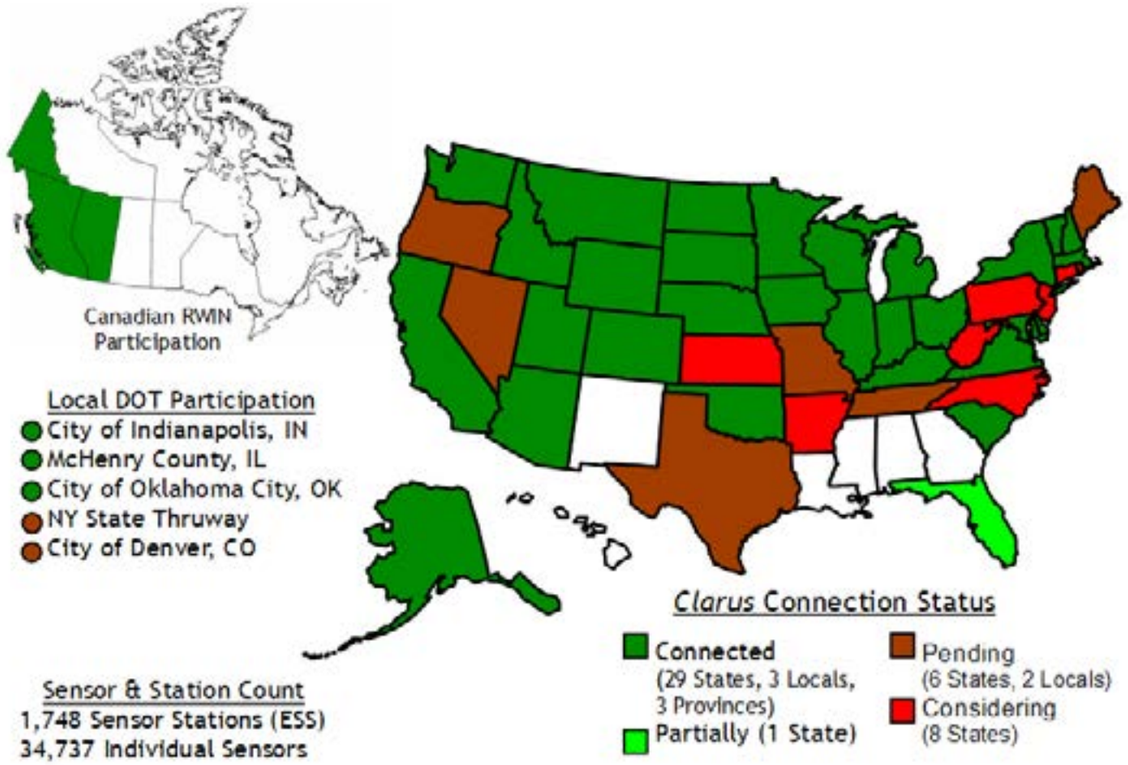
Since 2000, the FHWA Road Weather Management Program (www.fhwa.dot.gov/weather) has sponsored the development of a guidance tool for winter road maintenance decision makers. The tool, known as the Maintenance Decision Support System (MDSS) prototype, was created by a consortium of U.S. national laboratories with significant input and feedback from numerous state DOTs and commercial weather information providers. The MDSS prototype capitalizes on existing road weather data sources, fuses data to present integrated road weather observations and predictions, and generates recommendations on road treatment strategies with anticipated consequences of action or inaction. Treatment recommendations are based on standard practices for effective winter road maintenance (such as anti-icing, de-icing, plowing, sanding), which are tailored to the procedures of the local agency. The MDSS prototype was field tested during the winters of 2003 and 2004 in the state of Iowa. The FHWA has cultivated relationships with private vendors to foster integration of prototype modules into their product lines and development of applications tailored to the needs of state DOTs. Currently, MDSS technologies are being incorporated into the product generation routines of several private sector companies. (6)

By 2004, MDSS technologies were mature enough for private sector companies to incorporate MDSS capabilities into their product lines for State DOT clients. By 2007, 21 state transportation agencies were using or developing MDSS tools. Thirteen states have joined the MDSS Pooled Fund Study led by the South Dakota DOT to develop an enhanced version based on the federal MDSS prototype, while others are in the process of procuring the software or have contracted with private vendors for maintenance decision support capabilities. In 2008, the FHWA released an MDSS Deployment Guide (http://www.itsdocs.fhwa.dot.gov/JPODOCS//REPTS_TE/14439.htm). From 2007 to 2009, the FHWA conducted evaluations of operational MDSS applications being used by the pooled fund states, the Maine DOT, and the City and County of Denver, Colorado (2).

4.2 NEW MANAGEMENT AND ORGANIZATION APPROACHES

The FHWA Road Weather Management Program was formed in 1999, for coordination of snow and ice programs, among federal agencies and with the state and local constituencies. The program seeks to better understand the impacts of weather on roadways, and promote strategies and tools to mitigate those impacts. Envisioned is a system that provides "Anytime, Anywhere Road Weather Information" for road operating agencies and road users, as well as a robust, competitive market for road weather services. Program goals are to enhance observing capabilities, facilitate training and information dissemination, advance the state-of-the practice, and promote coordinated research.

In late 2004, the Road Weather Management Program began a new multi-year initiative called Clarus. The Clarus Initiative is an effort to develop and demonstrate an integrated surface transportation weather observation data management system, and to establish a partnership to create a Nationwide Surface Transportation Weather Observing and Forecasting System (2).



STATUS OF STATE, LOCAL, AND PROVINCIAL AGENCIES CONNECTED TO THE CLARUS SYSTEM

The vision of Clarus is to reduce the impact of adverse weather for all road and transit users and operators. Implementation of the Clarus system has demonstrated how an open and integrated approach to observational data management can be used to overcome deficiencies in road weather information products. Clarus has enabled public agencies to more accurately assess the state of their operations as they are affected by weather events. Such knowledge is critical for evaluating the effectiveness of winter road maintenance activities.

From 2004 to 2006, the U.S. DOT developed the Clarus advanced data management system that assimilates all ESS observations across the United States and provides quality checked road weather observations for any user. The Clarus System can be accessed at www.clarus-system.com. The system is an experimental product that is being used for evaluation and demonstration purposes. The transition of Clarus System functionality to the NWS operational system is expected to take place in 2011 (16).

The U.S. DOT has also initiated the IntelliDriveSM program (www.intellidriveusa.org) to develop an enabling communication infrastructure to support both vehicle-to-vehicle and vehicle-to-infrastructure communications in support of both safety and mobility applications. Safety applications will have an emphasis on crash avoidance. Mobility applications will allow access to better information for roadway system management and operations. This includes the potential to observe and infer both driver-level weather and pavement conditions. Several studies are planned to determine how best to process the potentially large amounts of data for the benefit of the surface transportation weather community (16).

The FHWA Road Weather Management Program has also sponsored foundational research on the characteristics and the feasibility of using vehicles as meteorological sensor platforms. Vehicles were equipped with air temperature sensors in the front bumper, near the engine air intake cowling, and in the rear bumper. The primary research areas included temperature bias vs. vehicle speed, mobile temperatures vs. in situ observations, importance of sensor placement, thermal characteristics of similar vehicles, and effects of external phenomena on mobile temperatures. Researchers also conducted a feasibility study to explore and assess the utility of using data from vehicles to improve surface transportation weather observations and predictions and road condition hazard analyses and predictions (2).

In order to enhance observation capabilities and define requirements for road weather observing systems, the Road Weather Management Program partnered with the Aurora Pooled Fund Program, and the AASHTO Snow and Ice Cooperative Program to develop siting guidelines for ESS in the roadway environment. The RWIS ESS Siting Guidelines, released in April 2005, provide a set of recommendations to support uniform siting of sensor stations that collect road and weather observations for RWIS. In 2006, the Road Weather Management Program initiated a project to implement and evaluate the guidelines in a field environment to ensure that the recommendations are realistic and that the contents are credible, understandable, and useful to the deployers. The results of this study are being used to refine the guidelines. As transportation agencies continue to invest in RWIS sensing technologies by installing new stations or adding sensors to existing stations, the refined guidelines will become a valuable tool to aid in their placement (2).

The Road Weather Management Program aims to promote a systematic approach to the significant challenge of managing traffic during adverse weather. Weather-responsive traffic management strategies view weather events and their impacts as predictable, non-recurring incidents that contribute to roadway congestion. In 2004, the program identified research needs to advance weather-responsive traffic management and began a study to examine use of weather information in Traffic Management Centers. In 2005 and 2006, the program quantified the impacts of various weather events on arterial and freeway traffic. Results from these empirical studies on traffic flow in inclement weather will support the development of guidance for state agencies and the incorporation of weather effects into traffic simulation models. In 2007, the program initiated a project to conduct a microscopic analysis of traffic flow in inclement weather. This project focuses on how weather events and associated road conditions affect driver behavior. The results will be a methodology for identifying and modeling microscopic traffic parameters that are influenced by poor road weather conditions and recommended procedures for incorporating findings into existing traffic microsimulation models.

UNITED STATES

The Road Weather Management Program also sponsored a research project to study how weather information is integrated into operations at 38 Traffic Management Centers (TMCs). In general, very limited integration and application of weather information for TMC operations were observed. Clearly there was a need to advance the state of the practice and help agencies overcome the challenges associated with weather integration in TMCs. To address these challenges, the Road Weather Management Program initiated a project to develop a self-assessment guide to help TMCs evaluate their weather information integration needs and assist them in creating a plan to meet those needs. The FHWA is working with two TMCs to conduct a self-assessment using the guide and develop a weather integration plan.

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